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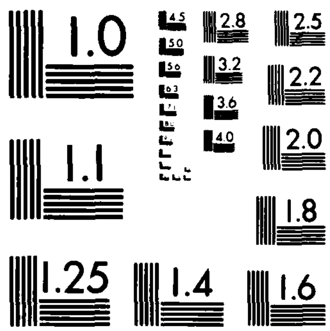
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PENTANET—A REPORT OF THE UNITED STATES AIR FORCE TECHNICAL PANEL FOR A PENTAGON-WIDE LOCAL AREA NETWORK

By
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MARCH 1983

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REVIEW AND APPROVAL

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In November 1981, the Assistant Vice Chief of Staff of the Air Force directed Air Force Systems Command (AFSC) Headquarters to provide an individual to serve as chairman of the Air Force Local Area Communication Network Panel. The Panel was established to explore and make recommendations on a Pentagon-wide local area network now known as PENTANET. Headquarters AFSC tasked the Electronic Systems Division (ESD) to provide the chairman, and a person was designated from the ESD Automated Management System Program Office (Project IMPACT). The panel was comprised of individuals from the Air Force (over)

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Communications Command, Air Force Electronic Security Command and Air Force Systems Command. The MITRE Corporation performed as technical advisor to the Panel. This report covers the Panel's findings on PENTANET.

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FOREWORD

Members of the Air Force PENTANET Technical Panel include:

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Mr. Keneth E. Becker, 1842 EEG/EEICS (AFCC)
Major Ronald Brocavich, ACDT (Hq AFSC)
Major Peter E. Donahue, AFDSDC/DMT (AFCC)
LTC William Johnston, AFDSC/CMT (AFCC)
Mr. Douglas R. Holden, AFCSC/EPE (ESC)

The Panel expresses its gratitude to all who have made contributions to this conceptual effort. Particular recognition is in order for our technical advisor, Mr. Charles E. Dolberg of The MITRE Corporation, for his contribution of technical material and his editorial support.

Ronald A. Creamer

PANEL CHAIRMAN

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SECTION 1

INTRODUCTION

The Air Staff has established the Air Force Local Area Communication Network Panel to explore and make recommendations on Air Force local area network (LAN) requirements for the Pentagon. This report covers the Panel's findings to date. The Army and Navy have established similar panels to address their respective requirements for a Pentagon local area communication network. It is a principal goal that all Services have a common solution. A common solution not only will facilitate communications among the Services, OSD and JCS, but also will provide a simpler and less expensive system to operate and maintain.

1.1 SCOPE

The technical aspects of this study have been coordinated informally with the Army and Navy LAN Panel Chairmen as well as with other key Air Force organizations.

The geographic area considered in this report involves the entire Pentagon. In addition, the Air Force has requirements for interconnections between the Pentagon and Bolling Air Force Base, the Webb Building in McLean, Virginia, the Commonwealth Building in Rosslyn, Virginia, and possibly the Personnel Center at Randolph AFB in Texas. Furthermore, the Navy has a requirement for interconnection with the National Center Buildings in Crystal City, Virginia. At the time of this writing, the Army has not expressed requirements for interconnections external to the Pentagon. However, the Army did indicate that such requirements were a distinct possibility.

The system will be multimoded, supporting low, intermediate and high-speed data as well as voice, facsimile and video communications.

Security-wise, the system will be "black," that is, all communication traffic passed over it will be either unclassified clear text, or will be encrypted (classified or unclassified) prior to entry on the network. Methods for managing the encryption/decryption will be considered external to the network. The same holds true for the interfaci g with "re l" subnet or stand-alone nets, wherein classified

clear text will be passed within the red net; nevertheless, when such information is to be transmitted over the Pentagon Local Area Network (PENTANET), it is incumbent upon the red net users to ensure that it enters encrypted with all associated TEMPEST requirements accommodated.

Commercially available, off-the-shelf technology will be employed in the local area net: there will be no dependency on research and development items concerning the technology utilized. The off-the-shelf technology is predicated upon those elements available in 1982.

What actually comprises a local area communication network can vary from definition to definition. This report defines the net as consisting of the Headend (the amplifiers, frequency translators, taps, splitters, power combiners, pads, and power supplies), the cable itself as well as the taps, amplifiers, splitters and outlets along the cable. Modulator/demodulators (MODEMS) and bus interface units (BIUs) are not considered as part of the network. Since they are essential for connecting terminals and host processors to the network, we have included appendices A and B which describe these critical interface devices.

SECTION 2

PENTANET OBJECTIVES

2.1 OVERALL OBJECTIVES

The overall objective of the Pentagon Local Area Network (PENTANET) system is to provide a cost-effective capability to handle all the information transfer services envisaged by the totality of office automation applications throughout the Pentagon and its environs. In providing such services, the system needs to support:

a. The exchange of data between local and remote interactive Keyboard Video Display (KVD) terminals and local and remote processors, wherein local and remote connote devices within and exterior to the Pentagon

b. The electronic exchange of variably formatted reports and documents between local and remote workstations

c. The local and remote distribution of digitally encoded graphic and facsimile products

d. The transfer of data files between local and remote processors and between local and remote peripheral devices

e. The transfer and distribution of teleconferencing and commercial video and associated analog voice, and low speed analog and digital control signals

f. The switching and exchange of analog and digitized voice signals between users

To provide such services now and in the future, the system needs to be able to handle low and high-speed digital data, low and voice rate analog, video and imagery signals. In the near term, the system must be able to handle the digital data traffic generated and/or used by a wide range of heterogeneous devices. These devices are built by various manufacturers and would include: interactive terminals, micro- and minicomputers, mainframe computers, and digital facsimile machines.

Also in the near term, the PENTANET system must be able to provide gateways to other networks, i.e., the common carrier Direct Distance Dialing (DDD) and Digital Data Service (DDS) networks; the Advanced Research Projects Agency (ARPA) network, and the military Automatic Digital Network (AUTODIN).

In the near term, the system only needs to be "black" in that all traffic handled by the system will be either unclassified clear text or text that is encrypted prior to entry into the system. Methods and procedures for handling the transfer and management of encrypted text will be external to the PENTANET system.

2.2 SPECIFIC OBJECTIVES

Specific objectives of the PENTANET system include:

a. The system needs to provide a high degree of availability, whereby availability is considered in terms of system reliability or Mean Time Between Failure (MTBF), "fail soft" characteristics, system maintainability or Mean Time to Repair (MTTR), and survivability. "Fail soft" implies the continuation of full service to some users, and survivability considers such catastrophic recurrences as fire and power blackout.

b. The system needs to provide high degrees of performance in terms of error rates, throughput and response times, transfer rates and transparency. Transparency connotes the capability to interface user devices to the network without any custom programming or protocol modifications in the users' devices.

c. The system needs to provide full connectivity between all user devices and provide simultaneous full-duplex, half-duplex and simplex information transfer as needed to support point-to-point, broadcast and multipoint-to-point service.

d. The system needs to be expandable not only to provide for new and/or additional services, but also to permit an increase in physical size to provide services in new areas. Expandability also includes the ability to handle multimode signals, i.e., voice, analog and video.

e. The system needs to include provisions for self-testing and monitoring of its operational capability so that uniquely-trained personnel are not required for maintenance.

SECTION 3

PENTANET SYSTEM OPERATION AND MAINTENANCE

The PENTANET system will be a joint service information transfer resource. Within this context, the system will be managed, operated and maintained as if it were a "public common carrier utility." This implies the establishment of a separate office or agency to manage and control the operation and maintenance of the system.

3.1 OPERATION

The operation of PENTANET involves management, coordination, planning, scheduling, budgeting, and implementing activities. Operation entails coordinating and validating users' requirements; maintaining control of the system configuration; planning, scheduling and allocating the use of the system; specifying, defining and controlling access to the system; establishing budgets and implementation plans; and preparing and issuing operation and management reports.

3.2 MAINTENANCE

The maintenance of the PENTANET system involves test, performance monitoring and repair activities. Test activities include: definition, acquisition and use of special system wide test equipment; conducting system level tests and evaluating results thereof. Performance monitoring entails identifying and locating any system performance anomalies while repairing implies restoring system operation.

Organization maintenance is limited to: (1) identifying and isolating faulty equipment at a "black box" level (2) replacing the "black box" and sending the unit to the supplying contractor for repair (3) replacing and checking the performance of the equipment and (4) conducting routine/preventive maintenance.

SECTION 4

ALTERNATIVE TOPOLOGIES AND ATTRIBUTES

A variety of alternative Local Area Network (LAN) topologies exist that may be appropriate for the PENTANET system. One LAN system can be distinguished from another on the basis of:

a. Applications and services offered
b. Information transfer attributes
c. Network topology
d. Underlying transmission medium
e. System level Technical Control and performance monitoring capabilities

This section outlines some basic topologies and their transmission medium, examines the information transfer attributes, and addresses the basic Technical Control issues of each topology.

The topology of a LAN not only determines the manner in which user devices and transmission links are interconnected, but also determines the types and capabilities of the information transfer services. Even though there are four basic topologies, most networks in actual use employ a mixture with one of the four types being predominant.

The following sections provide overview descriptions of star, ring, mesh, and bus LAN topologies. Following the overviews, table 1 lists the salient factors of each topology as they relate to the specific objectives listed in section 2.2.

4.1 STAR TOPOLOGY

In a star topology network, as shown in figure 1, each computer, terminal and other data handling device accepting or delivering data is connected via a dedicated line, usually twisted pairs, to a single central node through which all data traffic must pass. The central node acts as the system control and when messages are to be sent from one data handling device to another, the transmitting device makes a request to the central node for a connection. When the receiving device is ready, the central node establishes a communication path.

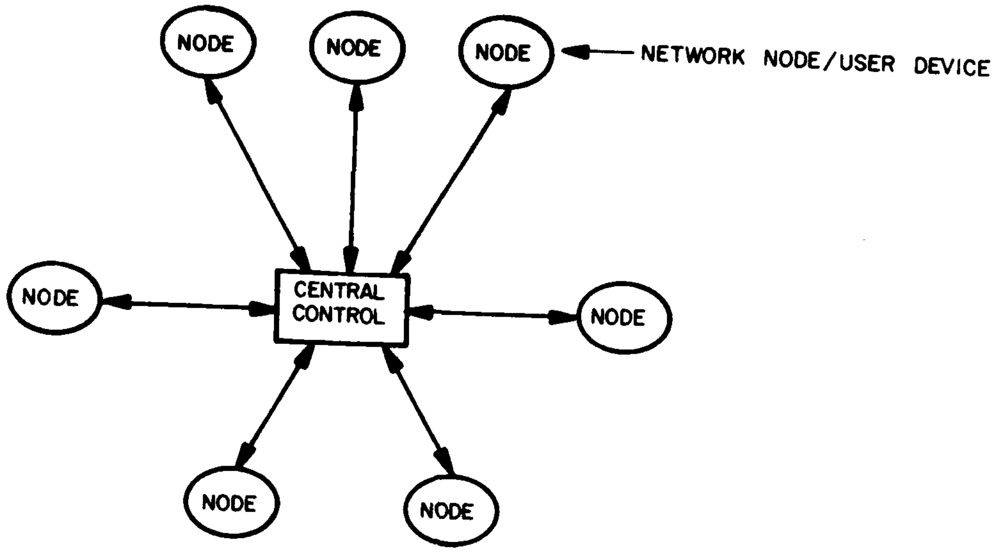

Figure 1. Single Star Topology

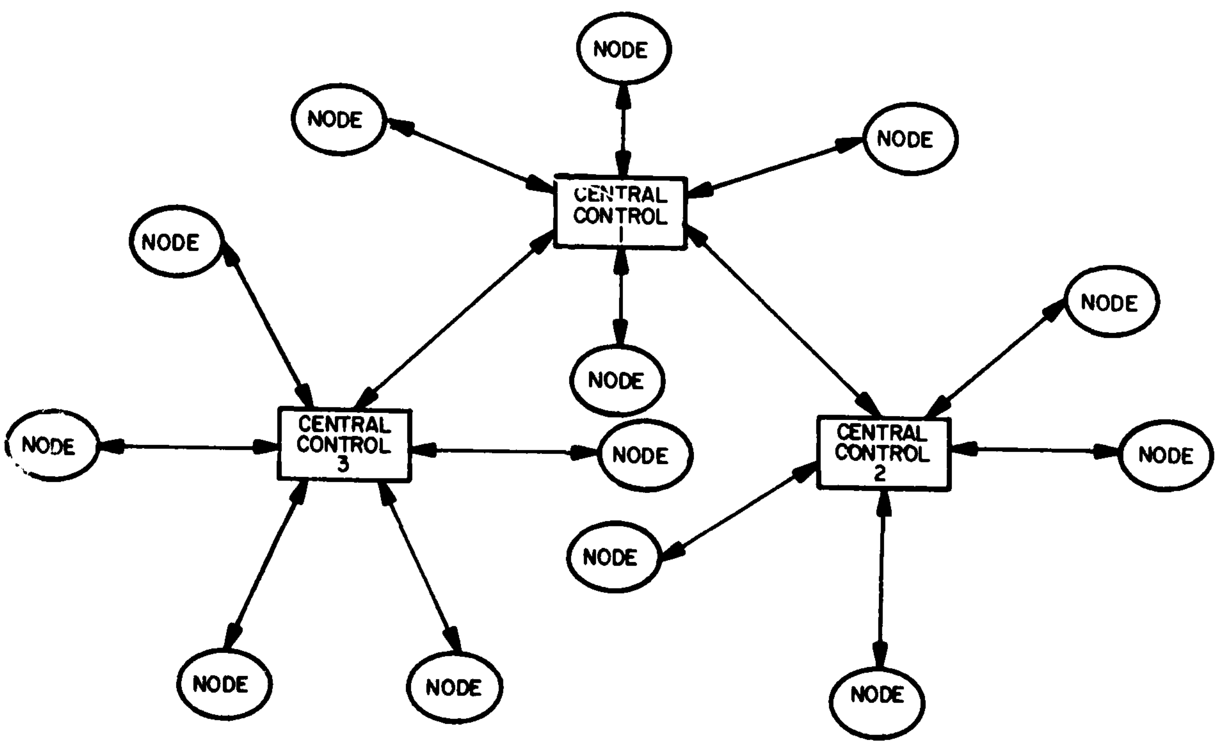

Figure 2. Multiple Star Topology

A failure in the central node would cause a "system wide" failure. Hence, the control node generally includes on-line diagnostics and performance monitoring capabilities.

Depending on the characteristics and type of the central node, star topologies generally are either a circuit switched or message switched system. In circuit switched systems, a connection or path (electrically or software implemented) between transmitting and receiving devices is established on demand for exclusive use of the circuit until the connection is released. Computerized Private Automated Branch Exchange (CPABX) systems are typical of circuit switched networks and provide information transfer data rates up to 64 Kbps. This type of star can handle voice and data traffic.

In message switching systems, only digital data is handled and the entire message is transmitted to the central node (a switching computer), stored until the receiver is able to accept the message, and then transmitted by the central node to the receiving device. The destination of each message is indicated by an address integral to the original message. Such store-and-forward processing is typical of distributed processing systems made up of a number of stars as shown in figure 2 whereby the central node of one star has the capability to communicate with the central node of other stars. The ability to interconnect stars not only allows for expansion to handle more devices, but also provides a gateway between two separate LANs.

In message switched systems, messages generally are divided into fixed-length "packets" for ease of processing, storing (buffering) and routing the messages by the central node. These are called packet switched networks. If a message exceeds the packet length, the excess is transmitted in subsequent packets and the last packet of a message is usually only partially filled. Depending on the capabilities and load on the central control, information transfer rates of about 2.0 Mbps are realized.

Each packet is handled separately from all others, thus allowing packets from different messages to be interleaved in processing and transmission to avoid monopolization of system resources by one long transmission. Hence, each packet not only contains the destination address but also includes a sequence number to ensure reconstitution of the transmitted message at the receiving end. Furthermore, each packet contains some type of error check code that is used by the receiving device to determine if errors have been introduced between transmission and reception.

4.2 RING TOPOLOGY

A ring network is shown in figure 3. It consists of nodes with connections only to the node on each side so that a complete circle or ring is obtained. With full-duplex links interconnecting the nodes, each node is able to transmit or receive messages in either direction on the ring. However, as indicated in figure 3, the more usual implementation of a ring toplogy is unidirectional using either twisted pair, coaxial or fiber optic cables, or a mixture of all three to interconnect the nodes.

When messages are sent from one node to any other, they are entered onto the ring, are received and retransmitted by each node, and travel around the ring until received by the addressed node or returned to the transmitting node. Depending on the implementation and protocol used, the message may be removed from the ring by either the receiving or the transmitting node. If the message must be removed by the transmitting node, a failure in any intervening node creates a total system failure. Some rings use redundant cables with passive "pick off" at each node. This tends to minimize this system failure aspect.

A ring network generally is one of three types: token passing, slotted, or delay insertion ring. The token passing ring entails round-robin passing of a control token (bit pattern) from one node to the next. The node with the token is able to transmit a message. The messages generally can be of variable length up to an arbitrary maximum length depending on the character of the data traffic and the number of nodes.

In a slotted ring, synchronization of the nodes is required and fixed time length slots are cycled around the ring. Two variations of slot usage are employed. In one variation, Demand Multiplexing, a bit pattern in each slot indicates whether the slot is full or empty. Whenever a node detects an empty slot, it can transmit a message or packet in that slot. In the other, Synchronous Time Division Multiplexing, each node is assigned a specific slot or set of slots for its transmissions. These assignments can be either an adaptation parameter at system start-up or controlled by a control node. This type of ring is often referred to as a "Loop." The control node provides a centralized performance monitoring capability. Hence, most rings include some type of control node that can provide system level performance monitoring.

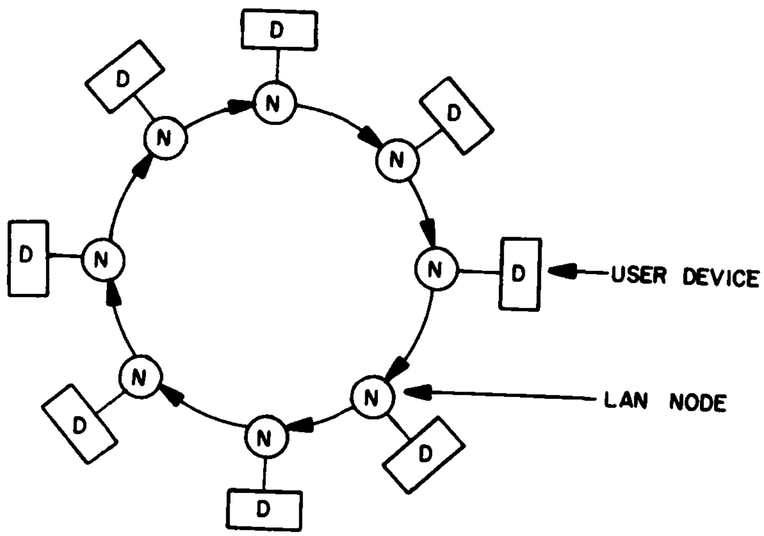

Figure 3. Ring Topology

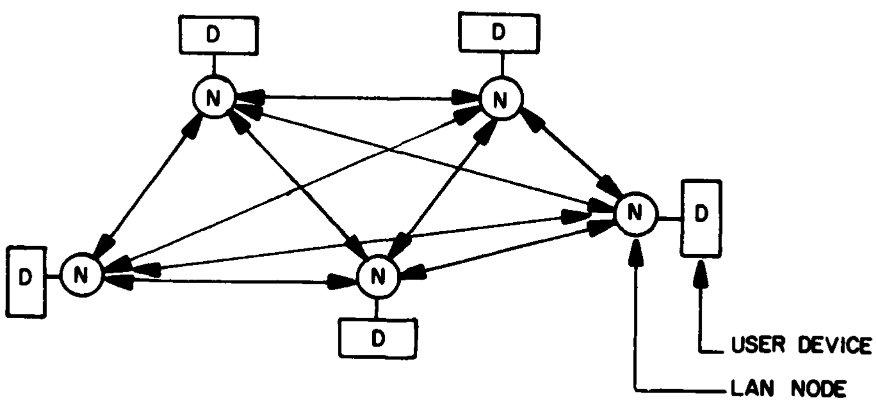

Figure 4. Fully Connected Mesh Topology

The delay insertion type of ring is characterized by a store-and-forward function at each node. Each node will buffer messages on the ring for a time needed by the node to insert a message on the ring, thus "squeezing in" ahead of the oncoming data traffic.

4.3 MESH TOPOLOGIES

Two classes of mesh topologies have been implemented. A fully connected mesh topology is portrayed in figure 4 and a partially connected mesh is depicted in figure 5. Both configurations permit all devices to interchange information.

The fully connected mesh has direct connections between all the devices and generally has been used to interconnect a small number of computers. If there are N computers to be interconnected, the network must provide $1/2(N(N-1))$ connections. Depending on the communications processing capabilities and interfacing adaptability of each computer, their separation and the interconnecting lines, effective and rapid information interchange is achieved. Depending on the characteristics of each connected pair of computers, the message structure and information handling protocols may be the same or may be different for each link.

The partially connected mesh, shown in figure 5, not only permits every device to interchange information with all others but also provides for at least two alternate paths. Since each node must have a store-and-forward capability, and be able to make a routing decision, each node is extremely complex.

The message traffic generally is in the form of fixed length packets, with each packet containing origin and destination addresses, sequence numbers and error check codes.

The information handling protocols are the same on each path and tend to be redundant because both end-to-end and node-to-node controls are needed for each packet.

Due to the complexity and cost of each node, few LANs with the partially connected topology have been implemented.

4.4 BUS TOPOLOGY

The term "bus" signifies that all information exchanges between users are handled by a common transmission medium, means that all information flowing in the bus is available to all parties connected to the bus, implies that it is possible for all users to interchange

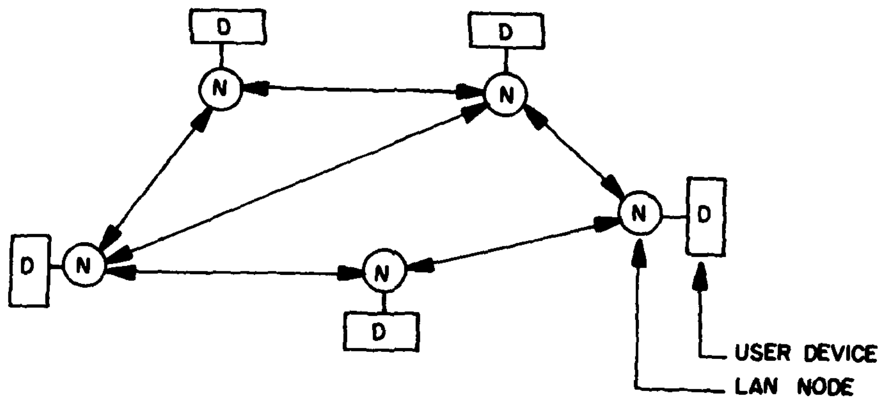

Figure 5. Partially Connected Mesh Topology

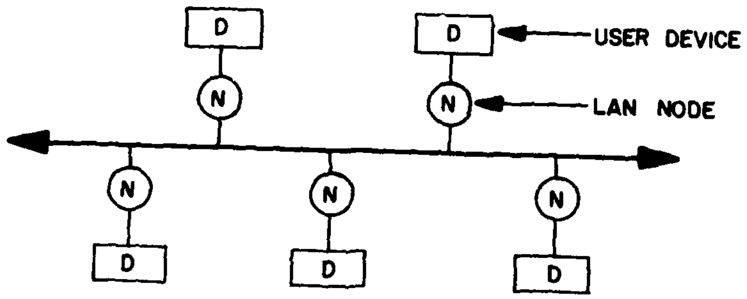

Figure 6. Bus Topology

information with each other and indicates full connectivity among all users. Users are connected to the bus through Network Interface Units (NIUs), or more commonly, Bus Interface Units (BIUs), and share the use of the bus on a time and/or frequency basis. Figure 6 depicts the basic bus topology.

Bus topologies generally can provide any one of three types of user interconnections:

a. Users are assigned communications on a permanent basis, essentially "virtual lines," by either dedicated frequencies or dedicated times (i.e., dedicated time slots).

b. Users contend for service on a moment-to-moment or message-to-message basis. This type provides "virtual circuits" wherein users contend for both service time and communication network frequencies.

c. A hybrid, or mix of the two.

Bus networks generally are either of two basic types: baseband or broadband. Both types generally employ coaxial cable as the distribution medium. However, some systems using fiber optic cables are being implemented.

Baseband networks have been designed and implemented primarily to handle digital data traffic, hence, provide a digital data bus. Broadband networks have been designed and implemented to handle coexistent digital data, voice, and image signals. Each signal type occupies one or more separate frequency channels within the broadband medium and each channel is a bus in its own right.

The number of users that a single digital data channel or bus in a broadband network can support is determined by the available bandwidth of the channel and the type of service needed by the users. Hence, several separate buses on the same distribution network may be needed in particular environments. In order to best match the information transfer capability of each bus to the various types of users and usage, different techniques of allocating the capacity among the various users are appropriate. A discussion of access techniques is provided in appendix C. The primary factors influencing the selection of the technique(s) for allocating the capacity include the transmitting data rate(s) of each subscriber's device, his transmit duty cycle, the access or throughput time each subscriber requires, and the degree of variety of connectivity required.

Inasmuch as each bus would be shared by a group of users in time in some orderly fashion, one way to broadly categorize bus allocation techniques is from the viewpoint of the users. This categorization is as follows:

a. Fixed capacity available
b. Capacity available upon request
c. Capacity available on a first-come-first-served basis

Within each of these three categories are variations and combination of allocation schemes to match particular application domains. Furthermore, within particular local environments, different groups of users may require different categories. Hence, hybrid considerations are important.

Fixed capacity or fixed assignment from a user's viewpoint means that at predetermined times, he has immediate access to the digital service. The amount of time may vary from a slot or few slots per frame in a Time Division Multiple Access (TDMA) system up to full time use of a dedicated FDM channel or a "virtual line."

Virtual lines generally are provided by Frequency Division Multiplex (FDM) modems. Descriptions of some commercially available FDM modems for use on broadband networks are provided in appendix A.

Fixed assignment techniques are appropriate for users who need synchronous, periodic or continuous service. One particular user that such an allocation would support could be the interface or gateway between the digital data bus and T-1 carrier systems. The BIU providing this interface would probably be assigned, on a fixed basis, sufficient data bus service time to support a T-1 carrier.

Capacity upon request includes reservation and polling techniques. These techniques are appropriate whenever the digital transfer service is being provided to a class of users whose demands for service change from time to time. For example, this change may be very rapid as a change from frame-to-frame in a slotted system wherein a user would request or reserve a number of slots in one frame and a different number the next frame. Reservation techniques generally are appropriate in an environment containing a relative small number of distributed processing elements.

Polling techniques involve a central node on the bus polling individual users. Unless a user has information to return, the central node will receive a negative acknowledgement. Whenever a polled source has information to transfer, a channel of digital communication is established. For centralized information processing applications, polling techniques are appropriate.

Capacity available on a first-come-first-served basis or contention techniques are appropriate for terminal-to-computer traffic. Several variations of contention techniques have been implemented. The most common one is Carrier Sense Multiple Access (CSMA) whereby the BIU or NIU of a user listens to hear if the bus is busy before beginning its transmission. A refinement of the CSMA technique involves collision detection wherein the BIU listens after transmission to determine if its transmission collided with some other BIU's transmission. By using the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) technique, a large number of terminal-to-computer interactions can be handled. Section B.1 of appendix B provides further details on the CSMA/CD technique.

Bus topologies generally provide for centralized system test and performance monitoring. A node at any point on the bus is implemented to provide the amount of capability needed for particular installations. For example, the node can generate test signals that traverse the bus and be evaluated upon their return, and receive and evaluate status messages that are periodically transmitted by all BIUs.

The BIU is the critical component in providing virtual circuits through broadband bus communications systems. It provides the interface to the coaxial cable distribution network via a radio frequency (RF) modulator/demodulator (MODEM); accomplishes sharing of the bus frequency channel among the users; provides buffering, speed conversion, error detection and correction, and protocol support for the connected devices; and performs the protocols for intranetwork information transfer.

The protocol support for the connected devices is provided through a combination of hardware logic and program control. (Refer to appendix C for a discussion of the generic protocol architecture within which the BIU operates). BIU designs provide the capability to:

a. Interface with devices which have either a bit-oriented or a character-oriented protocol

b. Acknowledge data or messages received from the devices as required

c. Comply with the device communication time-out parameters

d. Process special control messages and sequences

e. Determine from information supplied by the device the address of the recipient BIU and append this address to all information transmissions

f. Append its own address (origin address) to all information transmissions

g. Determine, in accordance with the device protocol rules, if the information received from the device is in error and request retransmission of any information received in error

h. Perform other special "handshaking" procedures required by the hardware or operating system software of the data handling devices

Appendix B contains descriptions of some commercially available BIUs and broadband LAN components.

4.5 TOPOLOGY/ATTRIBUTES

Table 1 provides a summary of the salient features of each topology as they relate to the attributes needed by PENTANET. This table, together with the overview description of the four basic topologies, supports the basic decision that the PENTANET system should be based on the use of broadband bus topology.

Table 1

Topology/Attribute Features

Attribute	Star	Ring	Mesh	Bus
Availability				
Reliability	Controller-central point of failure for entire system. Back-up machine difficult and expensive to implement. Failure in a node has minimal effect on system.	Failure in any node can break ring. Redundant nodes expensive. Vulnerable to errors in token pattern and addressing; thus creating circulating l ad.	Fully connected mesh - no central point of failure. Partially connected mesh - failure of one node still no system failure, may impact performance as remaining nodes have bigger loads.	In central ontrolled bus, a central failure shuts down entire system. On decentralized, tree - headend failure shuts down entire system; hence redundant headend elements usually are installed. Distribution components have long MTBF (i.e., 10-50 years).
Maintainability	Controllers usually have on-line diagnostics. Repair services centralized, hence potential for reducing MTTR.	Node failure detected in first downstream node. To maintain low MTTR, loop topology is capable of recognizing report packets generated by downstream node.	On both meshes, nodes generally have on-line diagnostics, repair services decentralized. No central point for system test and monitor purposes.	Centralized test and monitoring is used to identify and locate faults; thus reducing MTTR.
Survivability	Back-up power for central controller. Central controller can be protected against fire by HALON or equivalent systems. Lines to node vulnerable, redundant lines possible. If line fails, service is interrupted to only one node.	Back-up power to each node. Any node or section of ring subject to fire. Each node could be protected by HALON system. Redundant physically separated lines are possible, however node design complicated.	Each node is an entity in a fully connected mesh; back-up of each node is expensive and difficult to achieve; breakage of lines interrupts service only between two nodes. Partially connected mesh is highly survivable because of alternate paths.	Back-up power is provided for distribution network elements. Headend/gateways can be protected by HALON systems. Redundant, physically separated and opposite direction cable plant easy and relatively inexpensive to implement.

Table 1 (Continued)

Attribute	Star	Ring	Mesh	Bus
"Fail Soft"	Generally, full service or no service. Depending on types of nodes the nodes may be capable of stand-alone operation.	If ring is broken in unidirectional ring, entire system fails. Node design can provide passive "pick off"; thus minimizing impact of single node failure. In bidirectional ring, nodes on each side of break can exchange data.	Fully connected mesh explicitly provides a "fail soft" capability. Partially connected mesh is comparable. Depending on the number of alternate paths between nodes it can equal the fully connected mesh "fail soft" capabilities.	A failure in a broadband tree network branch permits operation in remaining branches. A failure in a node generally has no effect on other nodes in both baseband and broadband systems.
Performance				
Error Rate	Node/central usually are twisted pairs and provide about 1 in 10^5 bits. Circuit switch requires end-to-end error control. Message switch requires end-to-end as well as node-to-central error control.	Store-and-Forward operation requires node-to-node error control as well as end-to-end error control resulting in 1 in 10^{12} bits.	In a fully connected mesh, the error rate is dependent on characteristics of inter-connected nodes, types of connecting lines and protocols. With proper end-to-end (Layer 4) protocols, very low bit error rates are obtained. Partially connected mesh depends on node-to-node error control as well as end-to-end control. Bit error rates are comparable to fully connected mesh.	Baseband and broadband provide very low bit error rates - 1 bit in 10^{12}. Low error rate simplifies end-to-end error control.
Data Rates	Message switch up to 2.0 Mbps. Circuit switch up to 57 Kbps.	Burst rate in ring reaches tens of Mbps.	A fully connected mesh, is dependent on I/O capabilities of interconnected pairs. Partially connected mesh limited to about 1.0 Mbps, depending on type and capability of interconnecting lines.	Baseband up to 10.0 Mbps. Broadband, nominally 1.0 Mbps per data channel. Virtual lines up to 10 Mbps.

Table 1 (Continued)

Attribute	Star	Ring	Mesh	Bus
Transfer Times	Message switch, load/ traffic dependent. Overhead in packets or unfilled packets impact data transfer times. Long packets used to reduce overhead.	Small packet sizes plus overhead for error control impacts on transfer times; resulting in about 1.0 Mbps information transfer rate.	Fully connected mesh is device and line dependent. Partially connected mesh dependent on packet lengths, number of nodes in path, type of connecting lines, typical 50-70 Kbps.	Baseband - device dependent, long packets reduce overhead. Broad-band - CSMA/CD up to about 100 Kbps. Virtual link is device dependent - up to about 10 Mbps.
Transparency	Message switch requires another layer of proto-col in nodes (Communica-tion processor at nodes)	Node tailored to device. End-to-end protocol is device-to-device dependent. Generally not transparent to heterogeneous devices.	Fully connected mesh for homogeneous devices is transparent; for heterogeneous devices is non trans-parent in that adaptation to other device I/O required. Partially connected mesh transparent in that protocol con-version done in NIUs.	Baseband and broad-band virtual circuits - transparent (protocol conversions in BIUs). Virtual lines on broad-band - transparent device to device. With heterogeneous devices not necessarily trans-parent.
Connectivity	Node-to-node provided. Broadcast difficult and expensive to imple-ment. Gateway is provided via central to another central.	Node-to-node and broadcast provided. Gateway provided at a node.	Fully connected mesh is essentially point-to-point. Partially connected mesh is essentially limited to point-to-point. Limited broadcast capabilities are pos-sible with complications in NIU and device interface. A designated node can be a gateway.	Node-to-node, broadcast and multimode-to-node provided on broadband. Gateways are provided on both baseband and broadband.

Table 1 (Concluded)

Attribute	Star	Ring	Mesh	Bus
Expandability	Single control-traffic and I/O port handling limit additions. Other subservient stars can be added for "grouping" or clustering of services. Circuit switch handles data and voice. Message switch handles data only.	Insertion of new nodes into ring possible. Additional nodes impact throughput (response times). Ring handles data signals only.	Fully connected mesh has severe limitations since devices have I/O limitations. Partially connected mesh is expandable by adding additional nodes Both are limited to handling digital data signals.	Baseband bus is limited to about 2 miles; Broadband up to 25 miles. Baseband bus limited to few hundred nodes; broadband to few thousand. Broadband can handle video, voice, and digital virtual lines and virtual circuits. Baseband nodes are location dependent. Placement of node on broadband nodes immaterial.

SECTION 5

PENTANET SYSTEM CONCEPTS

The PENTANET system is considered to consist of three major interrelated elements:

a. The distribution network

b. The communication protocols used to manage the use of the network and to provide basic service to the users

c. The hardware and software facilities (Technical Control) used to test and monitor the operating condition of the system

It is intended that the PENTANET will be based on broadband bus topology and will use bidirectional coaxial cable distribution networks. The sections that follow outline four alternative broadband bus techniques and implementation concepts.

To achieve the bidirectionality, four techniques have been employed: subsplit, midsplit, highsplit and dual cable. The subsplit, midsplit and highsplit techniques are based on the use of a single coaxial cable with bidirectional amplifiers; in contrast, the dual cable has two one-way cables with one-way amplifiers.

In subsplit, midsplit and highsplit systems, the users transmit signals on one frequency band and receive signals from another frequency band. On dual cable systems, the users transmit signals on one cable and receive signals from the other cable. All four techniques require a "headend" whereby the transmitted signals either are converted in frequency or placed on the other cable for retransmission to the receiving devices. The physical architectures of all four generally are of a "tree" structure.

Independent of which technique is adopted, PENTANET would operate under a set of communication protocols consistent with the generic protocol architecture discussed in appendix C. Operationally, communication protocols are the formal set of rules established to provide an orderly and reliable exchange of information between computing equipments.

LANs use a formal set of protocols to control the transfer of information through the LAN. At the interfaces with the users' data handling devices, the LAN interacts with the protocols established for the device-to-device information transfer. At the gateways to other networks, i.e., AUTODIN, the Transmission Control Protocol (Version 4)/Interconnect Protocol (TCP/IP) would probably need to be implemented on the AUTODIN side of the gateway. The intent of TCP/IP is to provide reliable and error-free transmission over unstable and noisy environments such as AUTODIN.

The basic characteristics of a broadband coaxial cable LAN network provide a particularly stable and clean environment for information transfer. Vendors and designers have capitalized on this benign environment and have developed sets of protocols commensurate with this environment (refer to appendix C). Current commercially available LANs or components are not designed to handle TCP/IP for intranet transfers. In the event that commercial LAN products with TCP/IP capabilities become available, consideration should be given to utilizing them in PENTANET.

Independent of which technique is employed, it is anticipated that a centralized technical control facility would be implemented. This facility would provide the means to monitor and assess the performance of all of the various elements of PENTANET. At a central location, the technical control facility would detect faults or faulty operation, identify the location of the fault or inoperative component and present the necessary information to on-duty maintenance personnel so that repairs or isolation of the fault or failure can be quickly made.

Independent of which technique is employed, the future PENTANET is postulated to consist of a number of architecturally similar, interconnected LANs. The number of LANs is dependent on the type of bidirectional technique employed, the signal traffic requirements, and the number and types of devices requiring service. The LANs would interconnect through their headends. The headends and the gateways for interconnection to external communication networks would be collocated with the data processing facilities or computer centers of the various military departments.

Independent of which technique is implemented, redundant tree configured distribution networks would cover particular service areas, approaching each user's location from an opposite direction. Hence, if a fire or catastrophic failure occurs in one of the trees, users outside the immediate fire or catastrophic failure location could still have service.

Also independent of the technique employed, it is anticipated that several multiple access digital buses would be implemented in each coaxial cable. For example, one carrier sense multiple access (CSMA) bus could provide virtual circuit service to those users needing relatively low-speed, highly interactive service between their terminals and a central processor. The systems described in section B.6 of appendix B are potential candidates. Another multiple access bus could provide virtual circuit/virtual line service between users that require longer periods of higher data rate service. The system described in B.5 of appendix B is a candidate.

Furthermore, it is anticipated that each LAN would have a number of dedicated virtual lines for very high duty cycle, low- and high-speed service between user devices. The virtual lines would be established through the use of FDM modems of the type identified in appendix A.

The advantages and disadvantages of the four bidirectional techniques are discussed in the following sections.

5.1 SUBSPLIT TECHNIQUES

Subsplit systems use a single cable and provide for use of the 5 to 30 MHz frequency range for transmission toward the headend and 40 to 400 MHz for transmission from the headend.

Subsplit systems primarily are useful when little information originates at locations other than at the headend. If substantial information is generated at the other locations, multiple subsplit cables would be required and would seriously complicate the headend structure. Moreover, as with any single cable, bidirectional network, optimum amplifier spacing in one or both directions is compromised due to the change in attenuation as a function of frequency. In addition, subsplit systems possess the potential for signal distortion arising from interaction between inbound, outbound and receiver generated spurious signals, thus impacting the quality of service provided.

5.2 MIDSPLIT TECHNIQUES

Midsplit techniques provide for transmission toward the headend in the frequency band between 5 and 116 MHz, and for transmissions from the headend in the band between 168 and 400 MHz. Even though the midsplit techniques provide a more equitable division of usable frequencies than do the subsplit techniques, they also suffer from the potential interaction between transmit and receive signals and the problem of obtaining optimum amplifier spacing.

5.3 HIGHSPLIT TECHNIQUES

The advent of broader band amplifiers in the cable TV technology has resulted in the introduction of a new technique: highsplit. Highsplit techniques provide for transmission toward the headend at the frequency band bounded by 10 and 174 MHz, and transmission from the headend in the 225 to 400 MHz band.

5.4 DUAL CABLE TECHNIQUES

Dual cable systems provide for a 40 to 400 MHz frequency range for transmissions in both directions. Since each cable network is a mirror image of the other, optimum spacing of the amplifiers can be achieved. Since transmitted and received signals are on separate cables, no interaction between inbound and outbound signals is present and the design of headend is relatively simple.

Since the one-way amplifiers used in the dual cable systems are less espensive than the bidirectional amplifiers used in the subsplit, midsplit, or highsplit systems, the cost of a dual cable network generally is within 20 percent of the cost of a single cable network.

5.5 SUMMARY

In terms of the objectives discussed in section 2, the distribution networks of all three bus techniques contain components of established low MTBF rates. Because all provide decentralized access control a centralized technical control capability can be implemented for each to assist in maintaining a low MTTR. The survivability of each in the event of a fire or other catastrophic failure is comparable, as are the characteristics for "fail soft" modes.

The error rate performance of the single cable systems generally is poorer than that obtained with the dual cable system. This is due to the interaction of the transmit signals and receive signals on the same cable. The data rates handled by the networks are comparable within the allowed transmission frequency bands; and the transfer times, transparency, and connectivity characteristics are comparable.

The expandability of each in terms of providing new services primarily is dependent on the unused frequency spectrum. Obviously the dual cable provides greater potential, about twice the amount of signal carrying capacity of the midsplit. This capability, coupled with the separation of the transmission and receive signals, provides the opportunity to serve more users per network.

In summary, the PENTANET system should be based on the use of dual broadband coaxial cables, and provide a mix of virtual lines and virtual circuits to provide beneficial service to the users.

SECTION 6

PENTANET COST CONSIDERATIONS

Costs of the PENTANET system are divided between investment costs and Operations and Maintenance (O&M) costs. The investment costs include those costs incurred up to acceptance of the system and cover costs of system engineering, design, hardware, cables, software, installation and checkout up to the communication service outlets in the user areas. The investment costs do not include costs for the devices required to interface the users' equipment to the communication service outlets. However, appendices A and B show costs for some of the devices. Investment costs also include the costs of initial spares, system documentation, and system test equipment.

O&M costs are the ongoing costs of providing manpower to perform the operation and maintenance activities outlined in section 3, the costs of replenishing spares, and costs of contractor maintenance activities.

6.1 INVESTMENT COSTS

The estimate of the investment costs is based on experience in implementing LANs in other facilities, i.e., Walter Reed Army Medical Center (WRAMC), Lister Hill National Center for Biomedical Communications - National Library of Medicine, and Wilford Hall Medical Center. Experience has shown that a correlation exists between the number of service outlets provided and the total investment costs. Considering the type of construction used in the Pentagon, we estimate that the total investment costs would be about:

$425 times the number of outlets

For example, to provide service to 30,000 outlets, the total investment costs for a nonredundant dual coaxial cable system would be:

$425 x 30,000 = $12,750,000

Total investment costs for a fully redundant, physically separated system are estimated to be about $19,000,000. For a partially redundant, physically separated system, the total investment costs would be about $16,000,000.

The cost estimates are predicated on experience and do not reflect the explicit characteristics and needs for service within the Pentagon and its environs, and are not accurate within a desired range of $\pm 10\%$. System engineering and detail design efforts are prerequisites to defining cost estimates within the desired $\pm 10\%$ range.

6.2 O&M COSTS

The estimate of one-year costs is based on the costs or organization manpower. It is assumed that maintenance and repair service would be available 24 hours a day, seven days a week. Normal duty hours, i.e., 40 hours a week would involve the management efforts as well as providing maintenance. The manning is assumed to include a supervisor, a secretary and two technicians during normal duty hours, and one technician on duty at all other times.

The total O&M costs per year in 1982 dollars including personnel, replenishment of spares, and contractor repair services would be about $250,000.

SECTION 7

SYSTEM ACQUISITION PLAN

7.1 ACQUISITION STRATEGY

Initially, it is advisable to have a pilot local area communication network accessible to each of the major Services. The Services can gain first-hand experience in how to operate, maintain and use a local area network. By gradually extending accessibility to the network to the remainder of the Services according to an integrated, tri-service plan, we can avoid most of the trauma caused by the introduction of a turn-key system. Personnel can be trained on the pilot system and be in a position to exercise the full-scale network competently when it becomes available. The Air Force is currently designing just such a system (OPSNET) within the Pentagon for the Air Force Deputy Chief of Staff for Plans and Operation.

7.2 REQUIREMENT AND DESIGN INTEGRATION

In order for the Pentagon local area communication network to evolve in a homogeneous manner, guidelines will be necessary. Connectivity must be available among all noninsulated users, and controlled connectivity must be available to and from insulated users. Essentially, this means that while there might be three or more subnetworks within PENTANET, the system must be transparent to the user. The system designer's job is certainly far simpler if the systems (which must be bridged) have a common design with identical network components and protocols.

To ensure this, a system design effort must be accomplished which satisfies commonality requirements on the one hand, yet also satisfies unique user requirements on the other. The design job would be far simpler if the apportionment of space for each service within the Pentagon were more contiguous (e.g., an enti. floor for each Service). This is clearly not the case. While there are multifloored concentrations of Army, Navy and Air Force personnel within sectors of the Pentagon, there are also isolated Service enclaves quite remote from their parent concentrations.

These noncontiguous enclaves are cause for argument against physically different local area networks for each Service. If the requirement were firm for a physically distinct net for each Service, the design would inadvertently have Air Force cables passing through Army and Navy areas, Army cables running through Air Force and Navy areas, and so forth.

Dedicated, virtual subnets are possible for the Pentagon, although each virtual subnet might physically occupy three or more subnets. As long as the Air Force has 300 to 400 megahertz of available bandwidth on the PENTANET, it will not matter whether portions of it are physically resident on what happen to be designated as Army and Navy cables.

Considerations such as this are strong drivers for a unified PENTANET system. The Air Force Local Area Network Panel believes that there should be a subnet design engineer for each of the Military Departments, and an overall Pentagon-wide system design engineer to orchestrate the integration of the subnets into a cohesive, interoperable Pentagon Local Area Network.

One of the three Services or OSD should be designated as the Executive Agent for implementing PENTANET. The Executive Agent should be responsible for generating a detailed system design which is predicated upon both individual corporate requirements and integrated user requirements (including the Armed Services, OSD, JCS, DCA, DNA, and DIA). The Executive Agent should be responsible for the design, development, acquisition and implementation of the Pentagon Local Area Network. Since the Pentagon net will undoubtedly be the most unique and largest local area communication net in the world, it is essential that it be implemented by an organization that is experienced in one-of-a-kind, system acquisitions. Operation and maintenance of the network should be the responsibility of another organization such as the Defense Telecommunications Service.

7.3 PROGRAM MANAGEMENT

Having designated an Executive Agent for the Pentagon net, the Agent should be tasked to prepare a program management plan which delineates the key efforts and tasks for appropriate organizations to implement these efforts according to a comprehensive plan. It is important to designate early a Program Manager who would have tri-Service authority and responsibility, and who could plan, articulate and execute a course of action that would be agreeable to all interested parties. The Program Manager would establish a program office.

7.3.1 Management Approach

The program office will establish an overall system engineering capability for developing local area networks at the Pentagon. The system engineering will be characterized by the following:

a. Analysis of requirements to insure that system requirements are complete, consistent, feasible and testable, and that they are responsive to the users' operational needs.

b. Local area network design and development to resolve design issues pertaining to the choice of transmission medium, topology, control structure, protocols, performance, security and interconnection with long-haul networks.

c. State-of-the-art survey of commercially available and developmental local area networks and network components.

d. Evaluation of each proposed pilot local area network installation to determine the preferred pilot local area network for the environment and the performance of cost-benefit analyses as deemed necessary.

e. Installation and development of pilot local area networks at selected locations to establish an initial capability for proof-of-concept demonstrations and to facilitate evaluation of potential network components, services, protocols and performance and resolution of operational and user-oriented concerns.

f. Detailed design of local area networks for PENTANET.

g. Acquisition support for user, or program office acquisition of PENTANET.

h. Investigations of techniques and network designs for providing secure information transfer on a local area network.

The system engineering management program will insure that effective controls for the total engineering process are established, including subcontracted engineering. The program will result in coordinated and integrated system requirements, design efforts, and specialized engineering and logistics support activities. Requirements evaluation, design analyses, tradeoff studies, system optimization and cost assessment will be conducted throughout the program. The system engineering effort will determine the system configuration or configurations that should form the basis for full-scale implementation of the operational PENTANET.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on information presented in the preceding sections and supporting appendices.

8.1 BROADBAND VERSUS BASEBAND

Within the Pentagon, requirements exist for audio, video, facsimile, imagery and digital data communications. Since baseband local area networks (LANs) cannot accommodate simultaneous transmission of all of these modes, the panel recommends that PENTANET be based on the broadband technique.

8.2 TOPOLOGY

Star, ring, mesh and bus topologies have been examined. From the qualitative assessment of the composite attributes of reliability, complexity, cost, and performance, the panel recommends that the bus topology be employed.

8.3 MEDIUM

Transmission of communication traffic through the atmosphere by microwave or high radio frequencies presents many problems, the most severe of which is the security (refer to appendix D, Vulnerability Assessment). Twisted pair cables also present many problems, i.e., bandwidth, connectivity, noise intrusion and security considerations. Fiber optic technology, while excellent for point-to-point and security limitations, has not evolved sufficiently to provide the connectivity needed by the basic network. Coaxial cable is highly developed commercially, provides broadband (400 MHz) transmisison, presents desirable security characteristics and has been proven to be a highly reliable and flexible medium for existing LANs. Accordingly, the panel recommends that the basic transmission medium for PENTANET be coaxial cable. The panel also recommends that fiber optic cables be considered for both short and intermediate range point-to-point communications (e.g., Pentagon to Bolling AFB).

8.4 SINGLE VERSUS DUAL CABLE

Single cable systems handle all communications over one cable, allocating a certain portion of the cable bandwidth to handle communications being sent by user devices and allocating another portion of the bandwidth to handle communications being received by the user devices. These systems are reliable. However, substantial bandwidth is not usable for communications due to the presence of "crossover" filters needed for two-way communications over the same cable. Additionally, care needs to be taken to preclude the build-up of interference between transmitted and received signals.

Dual cable configurations use one cable (the inbound cable) for communications being sent by user devices, and a second cable (the outbound cable) to handle communications being received by user devices. Thus, they provide over twice the amount of usable bandwidth offered by a single cable at a cost of between 15 and 20 percent more. Additionally, the potential build-up of interference is diminished. Therefore, the panel recommends that PENTANET be configured with a dual coaxial cable design.

8.5 SECURITY

The nature of security within the Pentagon and between the Pentagon and outlying locations, as discussed in the separate classified appendix D, militates against a totally secure or "red" PENTANET system. Because of the security problems addressed in appendix D, the panel recommends that the basic distribution network, i.e., the broadband coaxial cable of PENTANET be black. This means that only unclassified information (or classified information properly encrypted prior to entry on the network) can be carried on the network.

Throughout the Pentagon and some offices in external buildings, numerous current and continuing requirements exist for the transfer of classified information. The panel recommends that for the near term, the use of "virtual lines," i.e., frequency channels in conjunction with link encryption devices of the type described in appendix D be used to handle the classified information. The panel also recommends that an effort be initiated to examine the "total system" issues from the users' point of view and not only define near term methods of transferring classified information from one point to another but also assess the application of various techniques for the long term (i.e., BLACKER II, the Data Encryption Standard (DES) and other evolving techniques).

8.6 REDUNDANT VERSUS NONREDUNDANT CABLES

Cabled-based LANs are inherently highly reliable. PENTANET likely will be comprised of three to five sub-LANs bridged to one another. Should a headend failure occur in a subnet, a portion, but not all, of the nonredundant PENTANET will be disabled. PENTANET can be made partially redundant, whereby critical components are redundant and carried as on-line spares. It can also be fully redundant, whereby the components, cables and outlets are duplicated in parallel. The panel recommends that the pilot networks be nonredundant, but so designed that redundancy may be added at any time, if deemed necessary, as the result of operational experience.

8.7 TRANSMISSION CONTROL PROTOCOL (VERSION 4)/INTERCONNECT PROTOCOL (TCP/IP)

TCP/IP is intended to provide reliable, error-free information transfer through unstable and noisy networks such as AUTODIN. The basic characteristics of a broadband coaxial cable LAN provide a particularly stable and clean environment. Designers and vendors of commercially available LAN systems and components, at the present time, have not incorporated TCP/IP within the intranetwork protocols. However, at the gateways between PENTANET and other networks such as AUTODIN, TCP/IP probably should be implemented on the AUTODIN side of the gateway. Therefore, the panel recommends that TCP/IP be considered for implementation only on the AUTODIN (or other) network side of the gateway. The panel also recommends that if and when commercial LAN components with TCP/IP capability become available, consideration be given to incorporating such capability within PENTANET.

8.8 DESIGN INTEGRATION

It is essential that PENTANET subnetworks have a common hardware design. To ensure this, the panel recommends that each of the services designates a design engineer who will be responsible for accommodating the technical requirements of his Military Department.

The panel further recommends that an organization be designated as Executive Agent for PENTANET acquisition; this organization will appoint a system engineer/program manager for the entire program.

Finally, the panel recommends that an existing organization be tasked to operate and maintain PENTANET subsequent to its acquisition.

8.9 COSTS

For a 30,000 outlet, nonredundant dual coaxial cable PENTANET, the acquisition cost would be on the order of $12,750,000. For a fully redundant, physically separated system, the total investment cost would be approximately $19,000,000. These costs do not include host processors and their peripherals, terminals, word processors, and bus interface units. The accuracy of these cost estimates may not fall within a desired range of $\pm 10\%$. The panel recommends that the cost estimates be examined in conjunction with a detailed system design and engineering effort in order to obtain higher confidence in their accuracy.

8.10 ACQUISITION STRATEGY

In view of the size of PENTANET, a turnkey acquisition of the sytem would generate considerable trauma among the users. The panel recommends that a pilot LAN be implemented to provide the users and maintainers with hands-on experience. As PENTANET is phased in, the experience with the pilot LAN will enable users to function effectively with the full system. The panel further recommends that PENTANET be acquired over a period of three contiguous years, and be phased by implementing one subnet at a time.

GLOSSARY

Abbreviations, Acronyms and Terms

A	Amperes
AC	Alternating Current
ACK	Affirmative Acknowledge
ADCCP	Advanced Data Communication Control Procedures
ANSI	American National Standards Institute
AP	Auxiliary Processor
ARPA	Advanced Research Projects Agency
ASCII	American Standard Code for Information Interchange
AUTODIN	Automatic Digital Network
BBN	Bolt, Beranek and Newman
BDLC	Burroughs Data Link Control
BISYNC	Binary Synchronous Communications
BIU	Bus Interface Unit
bit	Binary Digit
bps	Bits Per Second
C	Celsius
CATV	Cable Television
CC	Communications Card
CCITT	Consultative Committee on International Telegraphy and Telephony
COMSEC	Communications Security
CPABX	Computerized Private Automated Branch Exchange
CPU	Central Processing Unit
CRC	Cyclic Redundancy Code
CS	Control Space
CSMA	Carrier Sense Multiple Access
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
dB	Decibel
DCC	Digital Communications Corporation
DCE	Data Circuit Terminating Equipment
DEC	Digital Equipment Corporation
DES	Data Encryption Standard
DEMOD	Demodulator
DDCMP	Digital Data Communication Message Protocol
DMA	Direct Memory Access
DDD	Direct Distance Dialing
DDS	Digital Data Service
DTE	Data Terminal Equipment

GLOSSARY (Continued)

Abbreviations, Acronyms and Terms

EIA	Electronic Industries Association
EPROM	Erasable Programmable Read-Only Memory
ESD	Electronic Systems Division of Air Force Systems Command
FCS	Frame Check Sequence
FDM	Frequency Division Multiplex
FM	Frequency Modulation
FSK	Frequency Shift Keying
HDLC	High-level Data Link Control
HF/SSB	High Frequency/Single Side Band
Hz	Hertz (cycles)
IBM	International Business Machines Corporation
IDEAS	Information Development and Applications, Inc.
IEEE	Institute of Electrical and Electronic Engineers
I/O	Input/Output
IP	Interconnect Protocol
ISO	International Standards Organization
K	Thousand (1,024 when referring to bytes of storage)
Kbps	Kilo (thousand) bits per second
KHz	Kilo (thousand) hertz
Km	Kilo (thousand) meters
LAN	Local Area Network
LBT	Listen Before Talk
LED	Light Emitting Diode
LNLLC	Local Network Logical Link Control
LPI	Low Probability of Intercept
LWT	Listen While Talk
m	Milli or One Thousandth
Mbps	Mega (million) bits per second
mega	Million
MHz	Mega or Million Hertz
MOD	Modulator
MODEM	Modulator/Demodulator
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair

GLOSSARY (Continued)

Abbreviations, Acronyms and Terms

ms	One Thousandth of a Second
μP	Microprocessor
OPSEC	Operational Security
PENTANET	Pentagon Local Area Communication Network
NAK	Negative Acknowledgment
NCR-DLC	NCR Data Link Control
NIU	Network Interface Unit
NRZ	Non-Return to Zero
NRZI	Non-Return to Zero Inverted
NSA	National Security Agency
NVF	Network Virtual File
NVT	Network Virtual Terminal
OSI	Open Systems Interconnection
PAD	Packet Assembly and Disassembly
PDS	Protected Distributed System
PIU	Processor Interface Unit
PROM	Programmable Read-Only Memory
PSK	Phase Shift Keying
QM	Quadrature Modulation
RAM	Random Access Memory
RF	Radio Frequency
RFI	Radio Frequency Interference
ROM	Read Only Memory
SDLC	Synchronous Data Link Control
SYN	Synchronizing
TCP4	Transmission Control Protocol, Version 4
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TV	Television
UART	Universal Asynchronous Receiver Transmitter
USART	Universal Synchronous/Asynchronous Receiver Transmitter
UDLC	UNIVAC Data Link Control
V	Volts
VCP	Virtual Circuit Protocol
VSWR	Voltage Standing Wave Ratio

Definitions

ALOHA: A terminal-to-host packet communication system developed by the University of Hawaii to provide communications between terminals on the out islands and the host at Honolulu. The distribution network is a shared High Frequency/Single Side Band (HF/SSB) radio channel, and a simple contention protocol technique is used.

Asynchronous Transmission: A method of transmitting data in which each transmitted character is preceded by a start bit and followed by a stop bit, thus permitting the interval between characters to vary.

Baseband Coaxial Cable System: A system whereby information is directly encoded and impressed on the coaxial transmission medium. At any point on the medium, only one information signal at a time can be present without disruption.

BLACK: In LAN context, the distribution network handles both raw unclassified information and classified information that is encrypted prior to insertion into the network.

Broadband Coaxial Cable System: A system whereby encoded information modulates carrier frequencies and the resultant modulated frequencies are placed on appropriate frequency bands in the coaxial transmission medium. At any point on the medium, multiple information signals, each in its own frequency band, can be present without disruption.

Duplex: Simultaneous two-way independent transmission in both directions. Also referred to as full-duplex.

Full-Duplex: See Duplex.

Half-Duplex: A circuit designed for transmission in either direction but not both directions simultaneously.

Handshaking: The required sequence of signals for communication between system functions or between systems.

Definitions

Multimode: In LAN context, a mode connotes the nature of the information (e.g., voice) being handled. Multimode connotes the ability to simultaneously handle more than one mode. A multimode LAN, therefore, can simultaneously carry voice, video, facsimile, imagery and digital data information.

Parallel Interface: An interface that permits data transmission and receipt of all bits of a character or byte simultaneously either over separate communication lines or on different carrier frequencies on the same line.

RED: In LAN context, the distribution network is secure in that it handles raw classified information.

Serial Interface: An interface that permits data transmission and receipt of each bit of a character or byte in sequence on a single channel rather than simultaneously as in parallel transmission.

Simplex: A circuit designed for transmission in one direction only with no capability of reversing.

Synchronous Communication: A method of transferring serial binary data between computer systems or between a computer system and a peripheral device; binary data is transmitted at a fixed rate, with the transmitter and receiver synchronized. Synchronization characters are located at the beginning of each message, packet or block of data to synchronize the flow.

T1 Carrier: The Bell Telephone terminology for their digital transmission facilities.

TEMPEST: (1) An unclassified short name (not an acronym) referring to investigations and studies of compromising emanations. It is frequently used as an equivalent for the term "compromising emanations," e.g., "TEMPEST test" and "TEMPEST inspections." (2) A term applied to equipment used to transmit, receive, display, store, or otherwise process information in an electronic medium, meeting the electromagnetic radiation requirements of the National Security Agency.

GLOSSARY (Continued)

Definitions

Transparency: (1) The quality of a function performed by a device or system that is not noticed, seen or directly implemented by an operator or user. (2) The quality that a device to be interconnected to a network or system need neither software nor protocol modification for such interconnection.

Virtual Circuit: An apparent, as contrasted with actual or absolute, synthetic equivalent of a real point-to-point circuit that provides a connection (referred to as a virtual connection) between systems.

Virtual Connection: See virtual circuit.

RS-232C EIA Standard: Interface between data terminal equipment and data communication equipment employing serial-binary data interchange.

RS-449 EIA Standard: General purpose 37-position and 9-position interface for data terminal equipment and data circuit-terminating equipment employing serial-binary data interchange.

V.24 CCITT Recommendation: List of definitions for interchange circuits between data terminal equipment (DTE) and data circuit-terminating equipment (DCE).

V.35 CCITT Recommendation: Data transmission at 48 kilobits per second using 60-108 KHz group band circuits.

X.3 CCITT Recommendation: Packet assembly/disassembly (PAD) facility in a public data network.

X.21 CCITT Recommendation: General purpose interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for synchronous operation on public data networks.

X.25 CCITT Recommendation: Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for terminals operating in the packet mode on public data networks.

Definitions

X.28 CCITT Recommendation: DTE/DCE interface for a start/stop mode data terminal equipment accessing the packet assembly/disassembly (PAD) facility in a public data network.

X.29 CCITT Recommendation: Procedures for the exchange of control information and user data between a packet mode DTE and a packet assembly/disassembly (PAD) facility.

APPENDIX A

COMMERCIALLY AVAILABLE FREQUENCY DIVISION MODEMS

Several companies are manufacturing Frequency Division Multiplex (FDM) modems for use on broadband coaxial cable distribution networks. These FDM modems provide virtual lines through the network for interconnecting data handling equipments.

This appendix presents summary information on some FDM modems that could be used with bidirectional broadband coaxial cable distribution networks. The identified units can provide half-duplex or full-duplex virtual lines and can be ordered to use the particular RF frequencies needed by the installed distribution network. Care needs to be exercised in obtaining the units in accordance with an overall frequency utilization plan.

The width of the RF channel needed by a pair of FDM modems is determined by the information data rate and the type of modulation/demodulation used. Most vendors use either frequency shift keying (FSK) or phase shift keying (PSK). However, those products that provide high data rates may have some type of quadrature modulation (QM) to reduce the width of the RF channel.

Most of the modems provide a point-to-point virtual line. However, some provide for a multidrop configuration whereby a number of modems use the same frequency channel and are "polled" by a channel control modem. Thus, the channel is shared in a Time Division Multiplex (TDM) fashion.

The following paragraphs identify the vendors and their products.

A.1 JERROLD ELECTRONICS

P.O. Box 487
Byberry Road & Penn. Turnpike
Hatboro, PA 19040

A.1.1 BroadCom Data Commander

Circuit Configuration: Point-to-point
RF Channel Width: 60 KHz
Data Rates: Synchronous: 1.2K, 2.4K, and 4.8K bps
Asynchronous: 75 to 10K bps
Device Interface: RS-232-C
Price Class: $900

A.2 AMDAX CORPORATION

160 Wilbur Place
Bohemia, NY 11716

A.2.1 Model 740

Circuit Configuration: Point-to-point
RF Channel Width: 96 KHz
Data Rates: Synchronous: 150, 300, 600, 1.2K, 2.4K, 3.6K, 4.8K, and 19.2K bps
Device Interface: RS-232-C
Price Class: $1,000

A.2.2 Model 741

Circuit Configuration: Point-to-point
RF Channel Width: 96 KHz
Data Rates: Asynchronous: 110 to 19.2K bps
Device Interface: RS-232-C
Price Class: $1,000

A.2.3 Model 746

Circuit Configuration: Point-to-point
RF Channel Width: 96 KHz
Data Rates: Synchronous and Asynchronous: 110, 150, 225, 300, 450, 600, 900, 1.2K, 1.8K, 2.4K, 3.6K, 4.8K, 7.2K, 9.6K, 14.4K, and 19.2K bps
Device Interface: RS-232-C
Price Class: $1,200

A.2.4 Model 1140

Circuit Configuration: Point-to-point
RF Channel Width: 192 KHz
Data Rates: Synchronous: 50K and 56K bps
Device Interface: Bell 303 or CCITT V.35
Price Class: $2,500

A.3 E-COM CORPORATION

320 Essex Street
Stirling, NJ 07980

A.3.1 TRU-100

Circuit Configuration: Multidrop (TDM)
RF Channel Width: 250 KHz
Max. Nodes/Channel: 4096
Burst Transmission Rate: 38.4 Kbps
Channel Controller: TRC-180
Polling Packet Size: 8 bits
Data Rates: Asynchronous: 75, 110, 150, 300, 600, 1.2K, 2.4K, 3.6K, 4.8K, 7.2K, and 9.6K bps
Device Interface: TRX-102; 20 ma current loop
TRX-103, RS-232-C
Price Class: TRC-180 - $2,500
TRU-100 - $300 (Basic Unit)
TRX-102 - $150
TRX-103 - $150
Note: TRX-102 and TRX-103 each need a TRU-100.

A.4 INTERACTIVE SYSTEMS

TelComm Products Division/3M
3980 Varsity Drive
Ann Arbor, MI 48104

A.4.1 800 Series

Circuit Configuration: Multidrop (TDM)
RF Channel Width: 800 KHz
Max. Nodes/Channel: 248
Burst Transmission Rate: 100 Kbps
Channel Controller: Model 310
Data Rates: Asynchronous: 150, 300, 600, 1.2K, 2.4K, 4.8K, 9.6K, and 19.2K bps
Device Interface: RS-232-C, Model 810 - 8-bit TTL
Device Interface Ports: Model 830 - 1 port
Model 820 - Up to 4 ports
Price Class: Model 310 - $2,500
Models 810 & 830 - $900
Models 820 & 840 - $1,200

A.4.2 Model 620

Circuit Configuration: Point-to-point Concentrator
RF Channel Width: 800 KHz
Burst Transmission Rate: 7.2 Kbps
Data Rates: Asynchronous: 150, 300, 600, 1.2K, 2.4K, and 4.8K bps
Device Interface: RS-232-C
Device Interface Ports: 6 @ aggregate rates up to 7.2 Kbps
Price Class: $1,000

A.4.3 Model 630

Circuit Configuration: Point-to-point Concentrator
RF Channel Width: 800 KHz
Burst Transmission Rate: 7.2 Kbps
Data Rates: Asynchronous: 150, 600, 1.2K, 2.4K, 4.8K, 9.6K, and 19.2K bps
Device Interface: RS-232-C
Device Interface Ports: 6 @ aggregate rates up to 7.2 Kbps
Price Class: $2,000

A.4.4 Model 920

Circuit Configuration: Point-to-point
RF Channel Width: 100 KHz
Data Rates: Asynchronous: 0 to 10K bps
Synchronous: 600, 1.2K, 2.4K, 4.8K, and 9.6K bps
Device Interface: RS-232-C or 20 ma current loop
Price Class: $850

A.4.5 Model 930

Circuit Configuration: Point-to-point
RF Channel Width: 800 KHz
Data Rates: Asynchronous: 0 - 100K bps
Device Interface: RS-232-C
Price Class: $900

A.4.6 Model 950

Circuit Configuration: Point-to-point
RF Channel Width: 800 KHz
Data Rates: Synchronous: 1.2K, 2.4K, 4.8K, 9.6K, 19.2K, 38.4K, and 76.8K bps
Device Interface: RS-232-C
Price Class: $1,200

A.4.7 Model 6700

Circuit Configuration: Multidrop (Polling)
RF Channel Width: 6.0 MHz
Burst Transmission Rate: 4.717 Mbps
Data Rate: Synchronous: 2.358 Mbps
Device Interface: RG62 Coaxial, 93 ohms
Device Interface Ports: Model 6732 - 32 Ports
Model 6708 - 8 Ports
Model 6704 - 4 Ports
Price Class: Model 6732 - $6,300
Model 6708 - $3,400
Model 6704 - $2,600
Note: Interfaces IBM 3274 Control Unit to IBM 3270 Display Units

A.5 SCIENTIFIC ATLANTA

3845 Pleasantdale Road
Atlanta, GA 30340

A.5.1 Series 6400

Circuit Configuration: Point-to-point
RF Channel Width: Dependent on Data Rate - 20 KHz to 3.5 MHz
Data Rates: 50K bps to 10 Mbps
(Bell T1, 2T1, T1C, T2)
Device Interface: Bell DS1, DS2, and CCITT V.35
Price Class: $3,000

A.6 CATEL

1400D Steirlin Road
Mountain View, CA 94042

A.6.1 DM-2100

Circuit Configuration: Point-to-point
RF Channel Width: 200 KHz
Data Rates: Asynchronous: 2.4K to 28.8K bps
Synchronous: 2.4K to 28.8K bps
Device Interface: RS-232-C
Price Class: $1,500

APPENDIX B

COMMERCIALLY AVAILABLE LOCAL AREA COMMUNICATION NETWORK (LAN) COMPONENTS AND SYSTEMS

The dynamic nature of the marketplace for LAN products has forced many current manufacturers to offer new products and modify their product lines. Meanwhile, new vendors continue to enter the competitive arena with new product offerings. Hence, this appendix is intended to present summary information on some representative LAN components and system products that are appropriate for broadband-shared networks and is not intended to provide comprehensive information on all available LAN products.

The first part of this appendix, Sections B.1 through B.3, present information on three different bus interface units (BIUs). This information is followed by a discussion of LAN systems being offered by four different companies. Complete systems are products which offer some form of configuration management, software development, Technical Control, and internetworking in addition to a bus interface unit.

B.1 DCC BIU

The BIU being built by the Digital Communications Corporation (DCC) is based on the use of Carrier Sense Multiple Access with Collision Detection (CSMA/CD) techniques for contending for communications on the shared common digital bus.

The transfer of information between BIUs is handled by the CSMA/CD contention technique employing a nonpersistent Listen Before Talk (LBT) and a Listen While Talk (LWT) operation. No transmission is started by the BIU unless the bus, to the best of the transmitting BIU´s knowledge, is not in use (the LBT or carrier sense technique). A BIU sensing the bus busy reschedules the next time to sense the bus after a random delay (the nonpersistent LBT operation). The BIU listens to its transmissions to determine if its signal collided with another BIU´s transmission (the LWT or collision detection technique). If a collision has been detected, the BIU reinitiates the LWT/carrier sense operation before retransmitting.

A simplified block diagram of the DCC BIU is provided in figure B-1. The figure shows that the BIU consists of a processor module, a modem, and a power supply. These three elements, with room for another module, are mounted in a suitable metal enclosure.

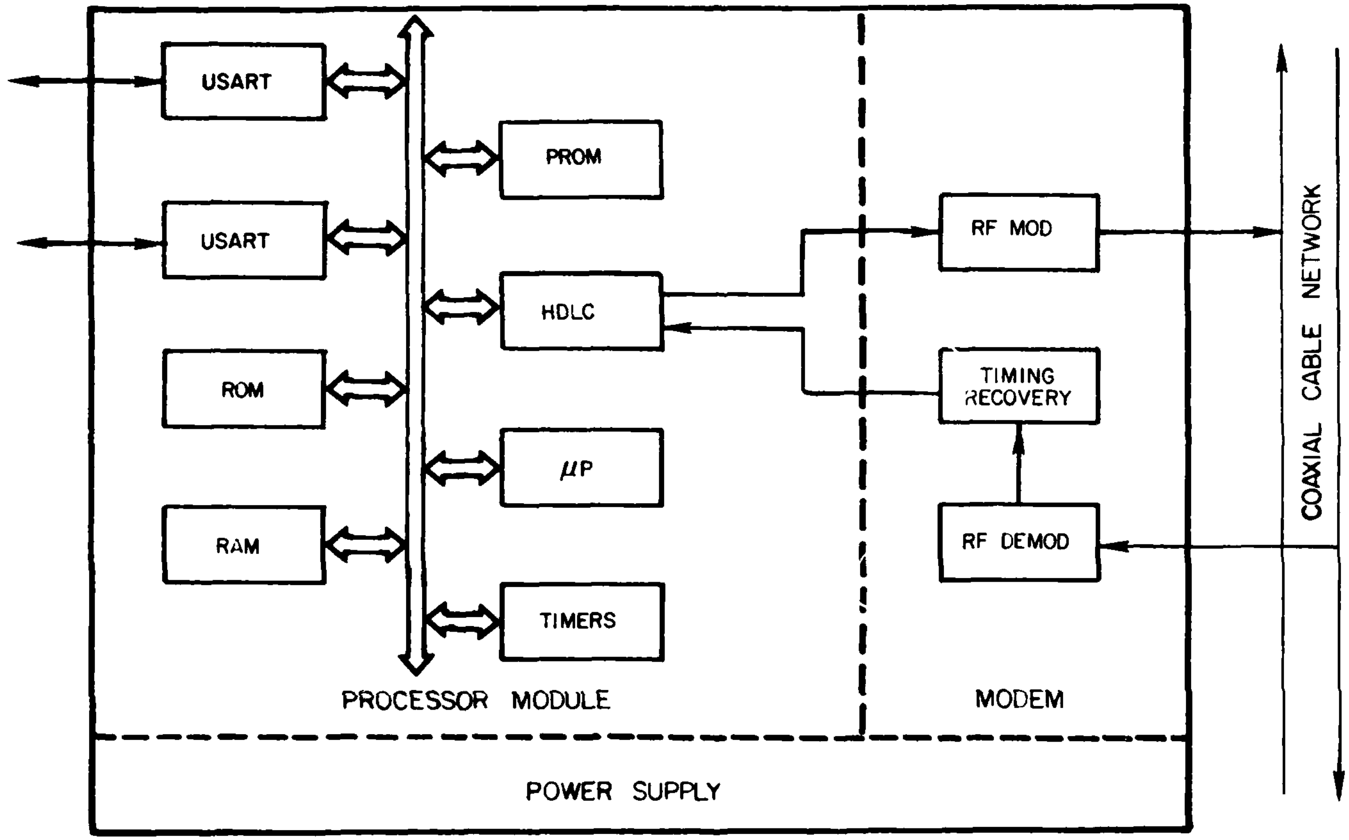

Figure B-1. DCC BIU Block Diagram

B.1.1 Processor Module

The processor module consists of a Z-80 microprocessor and its support circuitry, two RS-232-C data ports and a high-speed serial output port to the modem.

Each data port can be independently programmed to handle asynchronous data in any popular format or byte-synchronous data with up to two SYN characters. The data rate for each port can be selected from 50 bps to 19.2 Kbps using internal clock generation or up to 56 Kbps using an externally supplied clock. The internal clocks, as well as the port characteristics, are software controllable for ease of port configuration changing.

The high-speed port supports a bit-synchronous protocol such as HDLC at a data rate of 1.0 Mbps. Either NRZ or NRZI coding can be strap-selected, although NRZI operation is recommended to insure adequate data transitions for clock recovery purposes.

The processor module has memory capacity of:

ROM: 4K bytes standard, up to 16K bytes optional

RAM: 16K bytes standard

PROM: 32 bytes of fusible link ROM for nonvolatile storage of data port parameters, address, etc.

Three independent programmable timers exist on the processor module for miscellaneous timing functions such as real-time clock, etc. A separate watch dog timer is employed for software failure recovery.

B.1.2 Modem

The modem is an FSK modem operating at a nominal center frequency of 50 MHz. The center frequency can be changed by component substitution from about 20 MHz through 52 MHz.

B.1.3 Expansion Module

Room is provided in the enclosure for, and backplane wiring provided to, an expansion module which may contain two more RS-232-C ports for enhanced clustering capabilities.

B.2 IDEAS BUS INTERFACE UNIT

Information Development and Applications (IDEAS), Inc. is offering a CSMA/CD BIU to Government clients. The BIU consists of a chassis, power supply, a Z-80-based auxiliary processor (AP) board, and a Z-80-based communications card (CC) with an RF modem thereon. The combination is referred to as the CC/Modem board. These are each described below.

B.2.1 The BIU Chassis

The BIU chassis is housed in a cabinet that measures 4 1/2" high by 11" wide by 14" deep and weighs 12 pounds. The front panel contains an AC power switch, a system RESET switch, and three status Light Emitting Diodes (LEDs). The READY LED is used to indicate to the operator that the BIU is ready for operation and that it has completed a successful power-up sequence. The CONNECTED LED indicates that the BIU has established a connection with another BIU in the network and that it is ready to transmit and receive information to and from the cable. If a BIU becomes disconnected, the CONNECTED LED turns off and the READY LED turns back on. The third LED indicates an ERROR condition.

An error can be indicated on the CC/Modem board by the Watch Dog Timer when it times out (a software problem) or by the BIU carrier signal being on for more than 24 milliseconds (a hardware problem). This latter condition indicates the BIU is attempting to "hog" the network. When the ERROR LED turns on, the BIU should be powered down and removed from the network.

All the BIU cable connectors are located on the rear panel. There is a 60 Hz AC power plug and two auxiliary 60 Hz AC outlets. The coaxial transmit and receive cables connect to the rear panel via two BNC connectors. The RS-232-C connector is on the rear panel and an additional RS-232-C or RS-449 cutout is provided. The rear panel also has a TRANSMIT LED and a RECEIVE LED. These LEDs indicate whether the BIU is transmitting or receiving data from the network.

B.2.2 Power Supply

The BIU power supply operates at 117 VAC and consumes 40 watts of power. DC output specifications are:

Voltage	Actual Current	Maximum Current
+5V	1.5A	3A
+12V	0.15A	0.25A
-12V	0.05A	0.25A

The actual amount of current drawn from each DC supply is approximately one-half of the designed load current. This is to assure proper operation and to allow for future expansion within the BIU if necessary.

B.2.3 Auxiliary Processor Board

The function of the auxiliary processor (AP) board is to process data to and from the user side of the BIU. In the current configuration, the user side consists of RS-232-C terminal communications ports. The AP buffers the incoming data from the terminals and passes it to the CC/Modem board. Conversely, the data that the AP board receives from the CC/Modem board is buffered and sent to the RS-232-C terminal. The AP board is mounted as a "plug-in" module above the CC/Modem board within the BIU. Space is available for additional types of AP boards if other user interfaces are desired.

The AP board is a 7.5" x 4.5" printed circuit board. The board contains a Z-80 CPU and the system clock is 3.072 MHz. The maximum memory capacity of the board is 8K of PROM and 1K of RAM or 4K of PROM and 3K of RAM.

An 8251A USART provides data communications between RS-232-C terminals and the AP. Standard RS-232-C drivers and receivers are used. The 8251A operates asynchronously up to 19.2K bps and synchronously up to 64K bps. The bit rate, parity, number of data bits per character and number of stop bits per character are all programmable by the CPU. Parity, framing and overrun error detection are done by performing a status read from the USART. Break detection can also be tested by a status read.

B.2.4 Communications Controller/Modem Board

The CC/Modem board consists of a Z-80 microprocessor with two 8251A USARTS, a WD1933 SDLC chip to communicate with the modem, 24 bits of parallel I/O to communicate with the AP, a 4-channel counter/timer, a DMA controller, a system clock at 3.072 MHz and a modem section.

The 8251A USARTs can be used for an interface to two RS-232-C devices if necessary. A standard RS-232-C driver/receiver interface is provided with each USART. The USARTs operate asynchronously up to 19.2K bps and synchronously up to 64K bps. Bit rate, number of bits per character, parity and number of stop bits are all programmable by the Z-80. The CC/Modem board may be configured to allow for an interrupt each time either USART receives a character.

The CC/Modem was designed to transmit and receive data from the cable network at a rate of 1.152 Mbps. 1.152 Mbps is a character every 6.94 microseconds. Since a CSMA/CD access scheme must imply a Listen While Talk (LWT) function, the board must be capable of processing two characters every 6.94 microseconds or one character every 3.47 microseconds. This processing rate is beyond the capabilities of an 8-bit microprocessor to perform under program control. Direct Memory Access (DMA) techniques must be used. The Intel 8257 DMA unit is capable of processing a character every two microseconds and has been commercially available for some time. An 8237 will be commercially available in the near future. This device is plug compatible with the 8257 and it can process a character every microsecond. The 8257 is adequate for now, but an upgrade could be made if desired.

The WD1933 SDLC chip has some significant advantages over other SDLC chips. Specifically, the WD1933 is the only 2-megabit device that allows DMA circuitry to cause the transmission of an end-of-frame sequence without the intervention of the processor. It also has an address compare feature which reduces processor overhead. It has the ability to generate and check a frame check sequence (FCS), non-return to zero inverted (NRZI) encoding and zero insertion and deletion between flags of a frame. The frame format is shown in figure B-2.

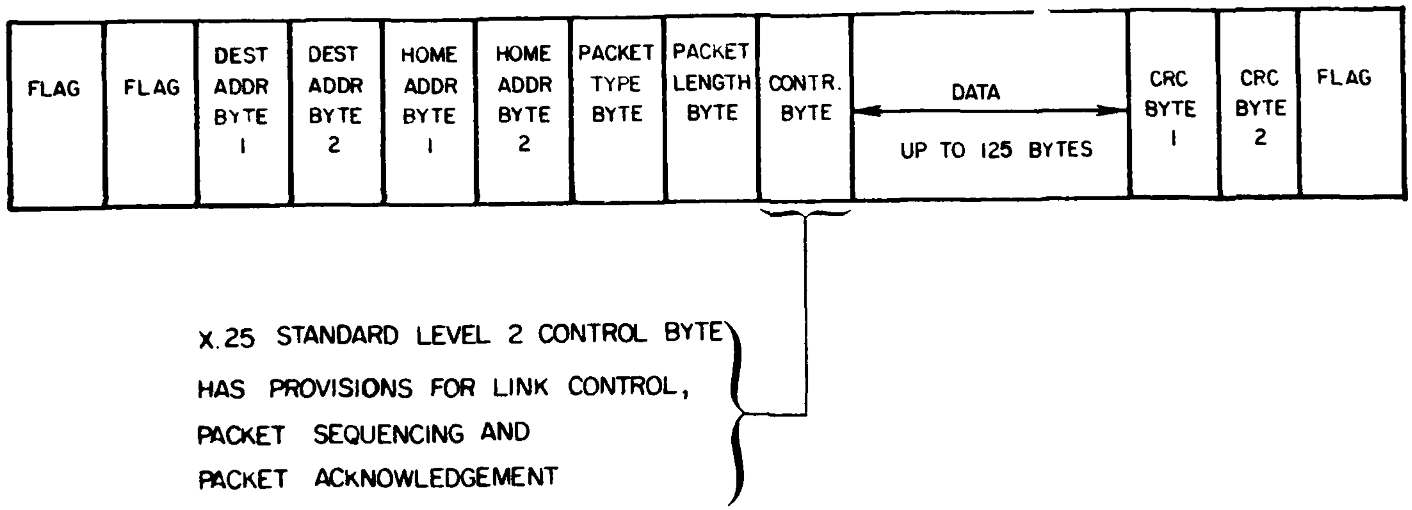

Figure B-2. IDEAS BIU Frame Format

The modem section consists of an RF transmitter module (Computrol, Inc., Model No. 30-0099) and an RF receiver module (Computrol, Inc., Model No. 30-0098). Both modules are packaged in metal cans and mount to the wiring side of the CC/Modem board. These cans are RFI shielded from the remainder of the box. The carrier frequency is 50 MHz for both transmit and receive modules. Maintenance costs are reduced by having no manual adjustments or a periodic alignment procedure required. The bit error rate is one error in 10^{12} bits over the normal operating range. The specifications for the modem are listed in table B-1.

Table B-1

IDEAS RF Modem Specifications

GENERAL

Center Frequency	50.0 MHz
Modulation	Phase Continuous FSK
Deviation	±5 MHz
Data Rate	Asynchronous: DC to 1.0 Mbps Synchronous: DC to 1.544 Mbps
RF Impedance	75 (VSWR 3:1 from 5 MHz to 300 MHz)
Operating Temperature	0 to 40°C

TRANSMITTER

RF Output Level	+60 dBmV ±2 dB average of mark and space levels
Balance	<1 dB difference between mark and space levels
Center Frequency	±100 KHz from nominal, average of mark and space frequencies
Deviation	±2% of nominal
On/Off Ratio	>100 dB
2nd Harmonic	<60 dB below carrier level
Other Harmonic and Spurious	<70 dB below carrier level

Table B-1 (Concluded)

RECEIVER

Center Frequency	± 50 KHz from nominal
Bandwidth	2.0 MHz ± 50 KHz at 6 dB
Discriminator Tuning	Zero crossover at ± 20 KHz from nominal center frequency
RF Input Level	0 to ± 20 dBmV

B.3 BOLT, BERANEK AND NEWMAN BIU OVERVIEW

BBN has designed BIU prototypes for selected Government applications. They are designed to operate on a single, midsplit broadband coaxial cable at a 1.0 Mbps rate. Employing Motorola 6809 processors, they utilize a CSMA access protocol with an HDLC-like link protocol. Packets are transmitted as unacknowledged datagrams, with each transmitter receiving and verifying the integrity of its own transmissions. Each packet's data field may be of variable length up to a maximum of 256 bytes. The maximum allowed subscriber separation from the headend is 2,000 feet.

Intended to ultimately pass TEMPEST requirements, the BIU is projected to cost approximately $13,000 in its fully expanded version. Each BIU is designed to be expandable in groups of two 9600 bps RS-449 ports up to a maximum of eight. Two maintenance ports are also available.

BBN has indicated an interest in selling only to Government clients and has, at present, no plans to commercialize their LAN product. Limited production is expected to begin in 1982. Table B-2 provides a summary of the BBN BIU.

Table B-2

Bolt, Beranek and Newman Bus Interface Unit

TRANSMISSION MEDIUM: Broadband coax with single, midsplit cable

NUMBER CHANNELS: 1 (6-MHz channel)

MAXIMUM NODES PER CHANNEL: 300 (performance limit)

MAXIMUM NODE SEPARATION: 2,000 feet from headend

BURST TRANSMISSION RATE: 1.0 Mbps

PACKET LENGTH: Variable up to 256 bytes data

PROCESSOR(S) USED: Motorola 6809

MEDIA ACCESS METHOD: CSMA with self-reception and verification of each packet

LINK PROTOCOL (ISO LAYER 2): HDLC-like

NETWORK PROTOCOL (ISO LAYER 3): Unacknowledged datagram

CONFIGURATION MANAGEMENT SCHEME: PROM replacement

TECHNICAL CONTROL SCHEME: In conceptual stage

INTERNETWORKING SCHEME: None at present

SERIAL INTERFACE(S): Up to eight 9600 bps RS-449 ports, two maintenance ports

PARALLEL INTERFACE(S): None

PRODUCT STATUS: Developmental

PRODUCT AVAILABILITY: June 1981 (prototypes)

PRODUCT PRICE: $13,000 per full 8-port BIU

FIELD REPLACEABLE UNIT: Circuit board

B.4 TRW LAN SYSTEMS

The TRW Corporation entered the local network field by virtue of their contract to install the SAFE system.

The SAFE system is designed to interconnect 2,000 to 10,000 video display terminals to a variety of computers. It accomplishes the interconnecting by using a dual-cable, broadband, CSMA bus. The system uses a collision-free, reserved interval after each transmission for acknowledgments. The system needs a multiplicity of 6 MHz frequency channels and uses frequency-agility techniques to switch users to different channels. In the maximum practical configuration, each frequency channel can have up to 250 terminals, and there can be up to 40 individual channels on the cable. The BIUs are controlled by a Z-80 microprocessor, and each 6 MHz channel now operates at a T1 data rate (or 1.544 Mbps). However, there are plans to upgrade this to 2 Mbps. The maximum cable length is 6,000 feet. The SAFE network will use an HDLC-like protocol (without sequence numbering) both as a link-to-link protocol and an end-to-end protocol. Each terminal will connect to the network via an EIA RS-449 port and operate at 9600 bps. In the SAFE network, terminals communicate only with hosts and not with each other. The Burroughs host computers in the SAFE network connect to the cable through Processor Interface Units (PIUs). The terminals, in turn, are connected to the cable through BIUs. The PIUs and Burroughs host computers interconnect by a parallel interface operating at 150 Kbits per second.

With the SAFE system, the terminals are capable of communicating with a variety of hosts, one at a time. A SAFE terminal uses a dedicated order wire channel (one of the 40 channels) to request a host connection from a Network Administrator computer. The Network Administrator assigns a frequency channel to the requesting terminal, thus, enabling the terminal to communicate with a host.

The host computers in SAFE intercommunicate by means of modified Hyperchannel technology. Hyperchannel is a bus system capable of operating at 50 Mbps. Table B-3 provides a summary of the characteristics, availability status, and expected costs of SAFE components.

Table B-3

TRW SAFE Wideband Communications System

TRANSMISSION MEDIUM: Broadband coax with separate inbound and outbound cables

NUMBER CHANNELS: 40 (6-MHz channels)

MAXIMUM NODES PER CHANNEL: 250 (performance limit)

MAXIMUM NODE SEPARATION: One mile from headend

BURST TRANSMISSION RATE: 1.544 Mbps to be upgraded to 2.0 Mbps

PACKET LENGTH: Variable up to 1,000 bytes

PROCESSOR(S) USED: Z-80

MEDIA ACCESS METHOD: CSMA with idle period following transmission to allow for collision-free ACKs

LINK PROTOCOL (ISO LAYER 2): HDLC-like

NETWORK PROTOCOL (ISO LAYER 3): Acknowledged datagram

CONFIGURATION MANAGEMENT SCHEME: Reassembly of code and/or jumper alterations, considering downline loading

TECHNICAL CONTROL SCHEME: System Controller and Monitor

INTERNETWORKING SCHEME: Future X.25 gateway planned

SERIAL INTERFACE(S): One 9600 bps RS-449 port, one maintenance port

PARALLEL INTERFACE(S): One 150 Kbps parallel port for interconnection with the Burroughs CPU

Table B-3 (Concluded)

PRODUCT STATUS: Developmental

PRODUCT AVAILABILITY: July 1981 (prototypes)
January 1982 (production)

PRODUCT PRICE: $2,000 - $2,400 per terminal (BIU)
$50,000 - $100,000 per processor (PIU)

FIELD REPLACEABLE UNIT: BIU, PIU

TRW also has established a program to produce a commercial version of some of the products resulting from the development efforts on the SAFE network. This program, called the Productivity Enhancement Program, is an in-house effort to provide automation support to TRW engineers. In many respects it is similar to the SAFE network with 250 terminals on a channel. However, it provides 54 channels on the cable. The reason for the greater number of channels vis-a-vis SAFE is that an improved coax cable network of 400 MHz bandwidth is being used. TRW hopes to increase the transmission rate to 2 Mbps as compared to 1.544 Mbps now being used for SAFE. Initially, two computer network interface units are being designed; one for an IBM interface and one for a DEC interface. These will operate at 250 Kbps as parallel ports to the computer. On this network, terminals will be able to talk to each other. In the future, TRW expects to be able to provide a gateway from their local network to X.25 networks.

Table B-4 provides pertinent summary information on the TRW Productivity Enhancement Network.

Table B-4

TRW Productivity Enhancement Network

TRANSMISSION MEDIUM:	Broadband coax with separate inbound and outbound cables
NUMBER CHANNELS:	54 (6-MHz channels)
MAXIMUM NODES PER CHANNEL:	250 (performance limit)
MAXIMUM NODE SEPARATION:	One mile from headend
BURST TRANSMISSION RATE:	2.0 Mbps
PACKET LENGTH:	Variable up to 1,000 bytes
PROCESSOR(S) USED:	Z-80
MEDIA ACCESS METHOD:	CSMA with idle period following transmission to allow for collision-free ACKs
LINK PROTOCOL (ISO LAYER 2):	HDLC-like
NETWORK PROTOCOL (ISO LAYER 3):	Acknowledged datagram
CONFIGURATION MANAGEMENT SCHEME:	Subscriber commands
TECHNICAL CONTROL SCHEME:	System Controller and Monitor
INTERNETWORKING SCHEME:	Future X.25 gateway planned
SERIAL INTERFACE(S):	Up to eight 9600 bps, RS-449 ports
PARALLEL INTERFACE(S):	One 250 Kbps parallel port for DEC and IBM processors
PRODUCT STATUS:	Developmental
PRODUCT AVAILABILITY:	January 1982
PRODUCT PRICE:	$1,000 per terminal (BIU) $10,000 - $100,000 per processor (PIU)
FIELD REPLACEABLE UNIT:	BIU, PIU

B.5 AMDAX LAN SYSTEM

The AMDAX Corporation is an established manufacturer of modems for the transmission of data. AMDAX is currently developing a local networking system called CableNet. CableNet has many unique properties and is projected as being competitive in performance with Ethernet. Ethernet is a baseband cable system which runs at 10 Mbps and supports a maximum station separation of 2.5 km and up to 1,024 nodes. CableNet uses a mid-split, broadband cable. One version of CableNet runs at 14 Mbps with up to 4,095 stations. No station can be more than 25 miles (40 km) from the headend. The other version runs at 7 Mbps with a corresponding decrease in the number of stations served. However, the 25-mile (40-km) separation from the headend is still permitted.

The AMDAX modem will be capable of modulating these data rates on a channel with a total bandwidth of 6 MHz for the 7 Mbps version and 12 MHz for the 14 Mbps version. Hence, the inbound and outbound traffic will require a bandwidth of either one or two TV channels (6 MHz per TV channel). The long network length and high data rate precludes the use of CSMA/CD access technology. Therefore, they have developed a unique network access method. This method is a combination of slotted ALOHA and a slot reservation technique.

At the headend of the network there is an AMDAX-designed bit slice computer called the CableNet Executive which controls the operation of the network. There are two models of the Executive to serve the two versions of Cablenet; the Executive 7 and the Executive 14.

The system operates with packet lengths of 512 bits. The CableNet Executive goes through a series of startup cycles before the network becomes operational. The initial cycle, called "ranging," is a poll of every potential station address on the network with a 16-packet guard time to allow an uninterfered-with response. Each active station responds to a poll by returning a packet which the Executive turns around and sends back out to the polled station. In this manner, every station confirms its startup message and can calculate the propagation time from the headend of the network. Next, there is a cycle of frames of 1,024 512-bit nonallocated packets. When stations want to transmit data, they contend for a nonallocated packet and place a reservation request for packets. There may be collisions when more than one station simultaneously attempts to access a nonallocated packet.

When a station has placed its reservation request on a nonallocated packet, the Executive assigns it time slots in succeeding frames. After the startup sequence and a number of the slots are assigned, nonallocated packets are also transmitted in each frame. These nonallocated packets allow stations that have not previously requested slots to do so. Nonallocated packets can also be used to send small amounts of information up to 364 bits. In addition, at the beginning or end of a frame, stations that have not responded to the original poll cycle are repolled at the rate of one or two per frame in order to allow them to synchronize their transmit modems.

There is a Network Manager on the network. This manager, an IBM Series 1 computer, examines the frames and determines whether reserved or allocated packets or slots are being utilized. If not, the manager rescinds the reservation and reassigns the slots.

Each station on the CableNet is called a "DAX." AMDAX has two versions of DAXs, a DAX7 and a DAX14, to match the two versions of CableNet. Each DAX has four communication ports. Three are used to connect to clustered user devices at data rates up to 19.2 Kbps. The fourth port is provided for diagnostic purposes. Table B-5 provides a summary of the AMDAX CableNet system, status, and expected cost of particular components.

Table B-5

AMDAX CableNet

TRANSMISSION MEDIUM: Broadband coax with single, midsplit cable

NUMBER CHANNELS: One 12-MHz channel for 14-Mbps Version
One 6-MHz channel for 7-Mbps Version

MAXIMUM NODES PER CHANNEL: 4,095 (Executive software limitation)

MAXIMUM NODE SEPARATION: 25 miles from Executive headend

BURST TRANSMISSION RATE: 7 Mbps
14 Mbps

PACKET LENGTH: Fixed at 512 bits

PROCESSOR(S): Z-80

MEDIA ACCESS METHOD: Slotted ALOHA/Slot Reservation

LINK PROTOCOL (ISO LAYER 2): LNLLC

NETWORK PROTOCOL (ISO LAYER 3): Datagram and acknowledged datagram

CONFIGURATION MANAGEMENT SCHEME: DAX Manager commands

TECHNICAL CONTROL SCHEME: DAX Manager

INTERNETWORKING SCHEME: None at present

SERIAL INTERFACE(S): DAX provides three 9600 bps RS-232-C or RS-449 ports, two configurable at 19.2 Kbps. All ports configurable to handle async, sync, BISYNC, SDLC and HDLC transmission formats, one maintenance port provided. SUPER-DAX provides up to 23 ports upgradable in increments of 4 ports, protocol conversions performed.

PARALLEL INTERF.CE(S): None

Table B-5 (Concluded)

PRODUCT STATUS: Developmental

PRODUCT AVAILABILITY: December 1981 (DAX, Executive)
May 1982 (SUPER-DAX, Manager)

PRODUCT PRICE:	Executive 7	- $8,950
	Executive 14	- $9,750
	DAX7	- $3,950
	DAX14	- $4,500

FIELD REPLACEABLE UNIT: Undecided

B.6 SYTEK LAN SYSTEMS

The SYTEK LocalNet System 20 is a midsplit cable broadband CSMA/CD system which uses a relatively narrow bandwidth of 300 KHz per channel. System 20 provides frequency-agile modems that can operate over 120 different channels. The modems are hardware selectable to operate in groups of 20 channels, and software addressable to a particular channel within the group of 20 channels. The packet length in the system is variable. On any one channel there can be a maximum of 200 subscribers. By providing for switching between channels through the use of a device called a TBridge, it is possible to have a maximum of 24,000 subscribers on the network (120 channels, times 200 subscribers per channel). A subscriber interfaces to the cable by means of a device called a TBox. The TBox uses a Z-80 microprocessor for communication control and also contains the frequency-agile, narrowband modem. The TBox can support two 19.2 Kbps RS-232-C terminal ports and contains a number of interactive commands in ROM so that a terminal user can establish the type of circuit he desires. Between TBox's, SYTEK operates its own proprietary Virtual Circuit Protocol (VCP), an adaptation or simplification of TCP-4 for end-to-end integrity, and a HDLC-like protocol for line protocol. In addition to the TBox, SYTEK also produces a multiplexed interface unit called a TMux. The TMux provides the capability for eight ports to access the cable.

System 20 also includes a TVerter. The TVerter is the device at the network headend which provides the frequency translation between the outbound channel and the inbound channel.

SYTEK plans to provide the TBridge as a product in the late-1981 to mid-1982 time period. The TBridge will provide frequency shifting based on addresses to allow interchannel communication. SYTEK is also planning to produce a TGate and a TLink. The TGate will act as a gateway to external networks, and the TLink will interconnect System 20 networks.

System 20 is primarily a terminal-to-host local network system and is relatively inexpensive per connection; $1,200 per TBox ($600 per port). The TMux and TVerter also are relatively inexpensive. It is possible to have both a network manager and Technical Control on the System 20 network. Because of the relatively low data rate per channel and the moderate number of subscribers allowed per channel, System 20 can have a very large geographical coverage for a local network; 30 miles (50 km) from the headend. Table B-6 provides summary data on the SYTEK System 20.

Table B-6

SYTEK LocalNet System 20

TRANSMISSION MEDIUM: Broadband coax with single, midsplit cable

NUMBER CHANNELS: 120 (300-KHz channels, dynamically selectable in groups of 20)

MAXIMUM NODES PER CHANNEL: 200 (performance limit)

MAXIMUM NODE SEPARATION: 50 kilometers from TVerter headend

BURST TRANSMISSION RATE: 128 Kbps

PACKET LENGTH: Variable

PROCESSOR(S) USED: Z-80

MEDIA ACCESS METHOD: CSMA/CD

LINK PROTOCOL (ISO LAYER 2): HDLC-like

NETWORK PROTOCOL (ISO LAYER 3): VCP (Virtual Circuit)

CONFIGURATION MANAGEMENT SCHEME: Subscriber commands, network directory service commands, network security service commands

TECHNICAL CONTROL SCHEME: Planned network Technical Control unit to use automatically collected TBox statistics

INTERNETWORKING SCHEME: TBridge (channel-channel)
TLink (LocalNet-LocalNet)
TGate (LocalNet-X.25 network)
Planned TCP4 TGate

SERIAL INTERFACE(S): TBox provides two 19,200 bps RS-232-C ports; TMux provides eight 19,200 bps RS-232-C ports

PARALLEL INTERFACE(S): None

PRODUCT STATUS: 15 systems installed, 120 TBox units total

Table B-6 (Concluded)

PRODUCT AVAILABILITY:	60-day delivery (TBox, TVerter headend) June 1981 (TMux) Late 1981 - mid 1982 (TBridge, TLink, TGate, Network Manager)
PRODUCT PRICE:	$1,200 per TBox $4,200 per TMux $3,500 per TVerter headend
FIELD REPLACEABLE UNIT:	TBox, TMux

SYTEK's LocalNet System 40 is a separate development. SYTEK claims it will be possible to use a System 40 TBridge to go between System 20 and System 40 channels. System 40 is a single, midsplit cable which provides five 6-MHz channels. Each channel operates at 2.0 Mbps CSMA/CD and can support up to 200 subscribers per channel. Because of this higher data rate, as compared to the System 20, the geographical coverage is now limited to 3 miles (5 km). Basically, System 40 is considered a host-to-host local network system as opposed to System 20. The host interface to System 40 is by means of a unit called a Network Adapter. This is a rather expensive unit which provides both high-speed parallel and serial interfaces to hosts. Between Network Adapter units, both the HDLC link level protocol and VCP operate.

A System 40 TBridge will allow for interconnection between the 5 System 40 channels or up to 1,000 interconnections, and will also permit bridging between System 40 and System 20 channels. The Network Adapter does not provide a universal interface to all hosts but, rather, has to be tailored for each host. Initially, the Network Adapter will be configured so that it can interface to a DEC UNIBUS and to IBM computers. It is also planned to have a serial interface which can interface to an X.25 network as well as an RS-232-C serial interface. Summary information on the SYTEK System 40 is presented in table B-7.

Table B-7

SYTEK LocalNet System 40

TRANSMISSION MEDIUM: Broadband coax with single, midsplit cable

NUMBER CHANNELS: 5 (6-MHz channels)

MAXIMUM NODES PER CHANNEL: 200 (performance limit)

MAXIMUM NODE SEPARATION: 5 kilometers from TVerter headend

BURST TRANSMISSION RATE: 2.0 Mbps

PACKET LENGTH: Variable

PROCESSOR(S) USED: 8086, 8089

MEDIA ACCESS METHOD: CSMA/CD

LINK PROTOCOL (ISO LAYER 2): HDLC-like

NETWORK PROTOCOL (ISO LAYER 3): VCP (Virtual Circuit)

CONFIGURATION MANAGEMENT SCHEME: Subscriber commands

TECHNICAL CONTROL SCHEME: Planned network Technical Control unit to use automatically collected Network Adapter statistics

INTERNETWORKING SCHEME: System 40 TBridge between System 40 channels and System 40/System 20 channels

SERIAL INTERFACE(S): RS-232-C, X.25

PARALLEL INTERFACE(S): DEC UNIBUS, IBM

PRODUCT STATUS: Developmental

PRODUCT AVAILABILITY: September 1981 (Network Adapter)

Table B-7 (Concluded)

PRODUCT PRICE: $8,515 per Network Adapter
$1,500 per DEC UNIBUS interface
$3,000 per IBM interface
$5,800 per System 40 TBridge
$3,500 per TVerter headend

FIELD REPLACEABLE UNIT: Network Adapter

B.7 WANG LAN SYSTEM

Wangnet represents a local area communications system intended to interconnect future Wang office automation and data processing equipment. It is based upon dual-coaxial cable, broadband CATV technology and consists of 4 frequency bands, together utilizing approximately 40 percent of the total cable bandwidth.

The Utility band provides seven TV channels of 6-MHz bandwidth each. These correspond to the commercial TV channels 7 through 13. It is Wang's view that the Utility band will generally be used for video conferencing, security monitors and the distribution of commercial broadcasts.

The Interconnect band consists of 16 channels suitable for up to 64-Kbps point-to-point or one-to-many data transfers using fixed frequency modems. In addition, there are 32 channels suitable for up to 9.6-Kbps point-to-point or one-to-many data transfers using fixed frequency modems. These channels are primarily intended to serve as twisted pair replacements and, as such, have no inherent switching or routing capability. Another group of 256 channels suitable for up to 9.6-Kbps data transfer does have a switching capability, however, and represents Wangnet's only vendor-independent local networking mechanism. Frequency-agile modems tuned to a channel controlled by a central data switch can request a connection to another modem. The data switch, via polling, detects the off-hook condition of the modem, interrogates it and decodes the request, identifies busy target modems and channels and, if possible, assigns both the requesting modem and target modem a free channel.

Because this latter frequency group is actually a circuit switched system, albeit a frequency division multiplexed one, it is effectively transparent to all protocols above the physical layer. Wang plans to provide modems with RS-232-C, RS-449, and RS-366 interfaces for use on the Interconnect band. Prices range from $850 to $1,250 for the modems, depending upon transmission rate, and $12,000 for the data switch. The modems are expected to be available in the first quarter of 1982 and the data switch around the middle of 1982.

The Wang band consists of a single 12-Mbps bus channel intended to interconnect only Wang equipment. As such, its interfaces and protocols are being kept proprietary. The bus access mechanism is CSMA/CD and the maximum allowed subscriber separation is two miles. Terminals can communicate on the Wang band only through their attached processors.

Wang band-compatible devices are expected to be available in the last quarter of 1982. At present, Technical Control and internetworking schemes are still in the conceptual stage.

The Peripheral attachment band is the most recently announced band in Wangnet, and its first primary application is to attach Wang terminals and printers directly to Wang processors on a local network. The band operates at 4.27 Mbps and uses TDMA as its access method. The older Wang terminals and printers, up to four at a time, connect through a multiplexer called the NETMUX to the Peripheral attachment band. The newer Wang terminals called the ERGO II and ERGO III can connect directly to the Peripheral attachment band. The Peripheral attachment band is expected to be available during the latter quarter of 1982.

Summary information on the Wangnet is provided in table B-8.

Table B-8

Wang Wangnet

TRANSMISSION MEDIUM:	Broadband coaxial cable with separate inbound and outbound cables
NUMBER CHANNELS:	Utility band - seven 6-MHz TV channels Interconnect band - sixteen 64-Kbps fixed point-to-point or one-to-many channels; thirty-two 9.6-Kbps fixed point-to-point or one-to-many channels; two-hundred and fifty-six 9.6-Kbps switchable point-to-point channels for frequency-agile modems Wang band - one 12-Mbps proprietary bus channel Peripheral band - several 6-MHz TV channels
MAXIMUM NODES PER CHANNEL:	Interconnect band - 1 transmitter, up to several thousand receivers Wang band - 65,000 Peripheral band - 512 processors @ 32 terminals/processor (16896 device connection)
MAXIMUM NODE SEPARATION:	Interconnect band - CATV limits Wang band - 2 miles Peripheral band - 2 miles
BURST TRANSMISSION RATE:	Interconnect band - up to 64 Kbps fixed, up to 9.6 Kbps switchable Wang band - 12 Mbps Peripheral band - 4.27 Mbps

Table B-8 (Continued)

PACKET LENGTH: Interconnect band - variable with no limits
Wang band - variable up to 2,000 bits
Peripheral band - variable up to 2,000 bits

PROCESSOR(S) USED: Variety

MEDIA ACCESS METHOD: Interconnect band - data switch polls all frequency-agile modems via separate control channel and then assigns unique data channels to those requesting connections
Wang band - CSMA/CD
Peripheral band - TDMA

LINK PROTOCOL (ISO LAYER 2): Interconnect band - transparent
Wang band - proprietary
Peripheral band - proprietary

NETWORK PROTOCOL (ISO LAYER 3): Interconnect band - transparent
Wang band - proprietary
Peripheral band - proprietary

CONFIGURATION MANAGEMENT SCHEME: Interconnect band - modem frequency for fixed frequency modems, data switch for frequency-agile modems
Wang band - subscriber control
Peripheral band - subscriber control

TECHNICAL CONTROL SCHEME: Conceptual (internal diagnostics planner)

INTERNETWORKING SCHEME: Interconnect band - transparent
Wang band - conceptual
Peripheral band - conceptual

Table B-8 (Concluded)

SERIAL INTERFACE(S):	Interconnect band - RS-232-C, RS-449, RS-366 Wang band - proprietary Peripheral band - proprietary
PARALLEL INTERFACE(S):	None
PRODUCT STATUS:	Developmental
PRODUCT AVAILABILITY:	Modems - January 1982 Data switch - June 1982 Wang band - October 1982 Peripheral band - September 1982
PRODUCT PRICE:	9.6-Kbps modem - $850 64-Kbps modem - $1,250 Data switch - $12,000 NETMUX - $15,000 ERGO Terminal Interface - $600
FIELD REPLACEABLE UNIT:	Modem

APPENDIX C

GENERIC PROTOCOL ARCHITECTURE

Data communications impose stringent requirements on the transfer of information, and these requirements are satisfied by employing strict sets of rules for the transfer. These sets of rules are called protocols. The operation and interaction of protocols can have a drastic effect on the reliability and efficiency of data communications, and a systematic way has evolved to describe and design such systems. This way is called a layered protocol structure and several standards organizations (ANSI, ISO, CCITT, IEEE, etc.), have been striving to standardize the protocol structure and the interfaces between protocol layers. An often cited protocol standardization effort is the Open Systems Interconnection (OSI) Architecture being developed by the International Standards Organization (ISO). Much work remains to be done in the protocol standardization arena and the ISO architecture is often used either as a guide to focus the directions of ongoing activities or as a basis for establishing protocol requirements.

The ISO architecture normally represented by the ISO Architectural Model is based on the idea that each host computer may have seven functionally independent hierarchical protocol layers between application programs and the communication network. Figure C-1 portrays the protocol layers in two hosts in accordance with the ISO model. The figure also shows the relationship of a LAN within the context of the ISO model. Layers 4 through 7 in the hosts are the end-to-end, (application oriented and transport oriented) protocols and layers 1 through 3 are the interface protocols used to interface a host to the LAN node. Layers 4 through 7 are logically identical in all hosts connected to the LAN, whereas layers 1 through 3 are specific to each interface from a host to its LAN node. Layer 4 provides the transport oriented protocol functions. Layers 5 through 7 provide the application oriented functions of the end-to-end protocols. The protocol layers implicitly define the execution order of the functions. That is, when a process desires to transmit information to another process in another host, the source host executes the layer 7 protocol functions first, and then executes, in

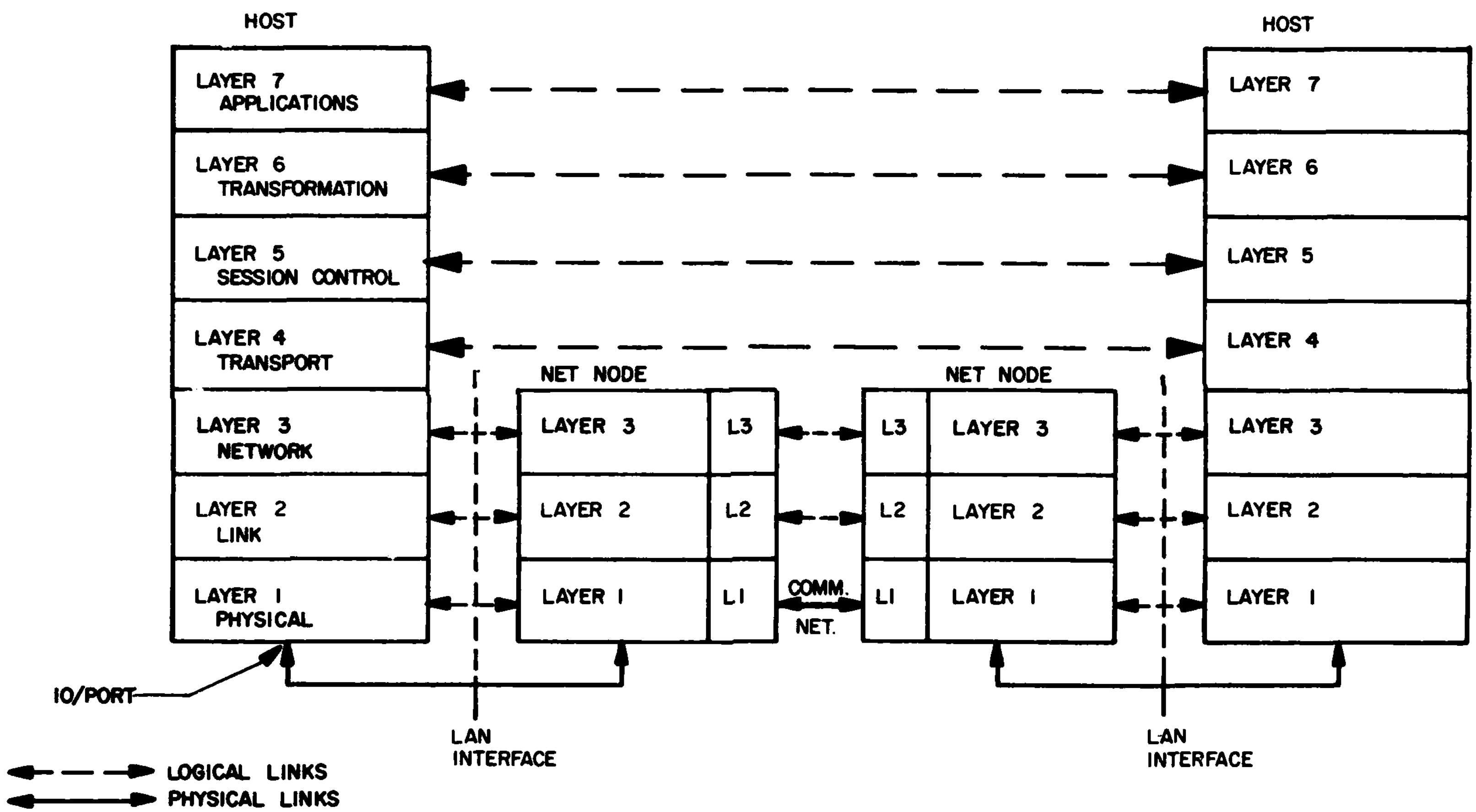

Figure C-1. Hierarchical Layered Protocols

descending order, the protocol functions in each of the successively lower layers of the protocol hierarchy. Eventually, the transmitted information moves from the host's layer 3 to the LAN node via sequential execution of the interface protocols (layers 3, 2, 1) across this boundary. Reciprocally, when a host receives information from the network, the host's layer 1 protocol functions are performed first, then the layer 2 functions, and so on. The layer 7 functions would then be the last tasks to be performed on inbound information before it is presented to the recipient application program.

The three layers of protocol on the host side of a LAN node are tailored to match the three layers in the accompanying host. Between LAN nodes are intranetwork protocols that have been established by different vendors to fill the needs of their particular LANs.

The types of functions performed in each of the protocol layers are identified in Sections C.1 through C.7. Section C.8 provides a discussion of the intranet protocols.

C.1 LAYER 7 PROTOCOLS

The purposes of the layer 7 protocols in the ISO model are to perform applications-specific aspects of interprocess communication. This includes any necessary control and supervision. The functions provided by this protocol layer are essentially threefold: applications support activities, applications management activities, and system management activities.

With respect to applications support activities, the layer 7 protocols serve each local process (e.g., application program) by providing the information service appropriate to the process. Because of the diversity of processes and their requirements for different types of information services, there can be a variety of functionally independent and concurrently executable layer 7 application support modules. For example, one application program, or a distributed data base management system, may need a network virtual file (NVF) protocol to perform such tasks as file management and manipulation (e.g., creation, access, transfer, deletion, and concatenation) for a logical file whose individual data elements may be physically dispersed onto several resources throughout the network. Another application program may need an electronic mail protocol, an electronic funds transfer protocol, a remote job entry protocol, an order entry protocol, or some other, as yet undefined, protocol. Such applications support modules can be so intimately related to the accompanying application program that an application process truly involves the joint execution of the application program as well as the application support protocol. Since the various layer 7 application support modules

interface local processes to the rest of the local protocols, these application support modules must cast all functional requests from each process into requests for services from lower protocol layers. Some of the specific functions performed by these layer 7 modules may include requesting connections, via the layer 5 session establishment procedures (Section C.3) to one or more (local or remote) application programs or resources, declaring (to the layer 6 transformation protocols) the acceptable modes of presentation of information to each local application program, and requesting specific modes of presentation to remote processes. These activities may include requesting specific initialization of the PAD parameters in an X.29 module in the layer 6 presentation layer or requesting a broadcast datagram transport service to locate a particular, remotely stored data element needed by a local network virtual file protocol.

In order to perform their functions, the layer 7 application support modules may need to call upon the services of any of several of the management activities available in the layer 7 protocol. These management activities are classified as either applications-oriented or system-oriented.

The applications-oriented management activities support the initiation, maintenance, control, accounting (for billing purposes) and termination of transparent information transfers (data or commands) between processes or between processes and logical resources (either of which may be physically located anywhere throughout the network). To facilitate this task the applications management activities must include initiating, maintaining and terminating processes, authenticating received information (e.g., by such mechanisms as electronic signatures), applications oriented error control (such as information editing/validation), and allocating and deallocating logical resources to processes. Furthermore, when application programs (either local or remote) share local data or local resources, the applications management activities (in conjunction with the local operating system) must detect and/or prevent resource deadlock and mutual interference (such as incorrect information flow) between competing application programs. Integrity must be preserved; that is, consistency of information and of information handlers (e.g., data base pointers) must be maintained by avoiding any interference or failures that could effect stored data.

The system management activities include such functions as activating physical resources distributed throughout the network, such as the disc where data pertaining to a particular NVF command is located, announcing to the network the availability of particular processes and application programs, reconfiguring and/or restarting processes and

supporting network-wide checkpoint and recovery procedures. A network-wide checkpoint might entail the following: at a given moment all network hosts are instructed to archive the contents of all buffers and registers and the values of all pointers (even the entire data base in each host can be copied to a backup device). Thus, in the event of a catastrophic failure, all programs throughout the network could be restarted from the same instant of time.

Many of the application-oriented and system-oriented management activities are traditionally thought to be operating system functions. Hence, the provision of such functions by the protocol has led to the genesis of the term "network operating system" to describe these aspects of the layer 7 protocol.

C.2 LAYER 6 PROTOCOLS

The purposes of the layer 6 protocol in the ISO model are to provide the set of transformations and manipulations selected by the layer 7 protocol to enable the local processes to interpret the meaning of the information being exchanged. These transformations can affect both the contents and structure of exchanged information. That is, the data, data manipulation commands (add, delete, update, etc.), and/or service requests contained in the exchanged information may have to be mapped/translated to and from locally understandable data, data manipulation language structure service operation requests, and/or service parameters. The structure (format) of the exchanged information may have to be rearranged into and from the structure (format) utilized by a given local process. The layer 6 transformation services thus permit local autonomy of character representations, data definitions, command formats. For example, a "SEARCH" command in one manufacturer's data base manager may be equivalent to a "RETRIEVE" command in some other data base manager that does not have a "SEARCH" command. Special purpose transformations such as encryption/decryption or compacting/expanding the contents of exchanged information (e.g., removing or adding blanks to generate a particular screen format) may occur at this protocol layer.

Since there can be many types of local processes each with specific local application support modules in the layer 7 protocols, it is possible that there can be many layer 6 transformation services for application specific mappings and translations. For example, the network virtual file (NVF) protocol in layer 7 can have a companion layer 6 NVF transformation protocol concerned with formatting of

virtual file commands. This protocol can provide conversions to and from local descriptions of file structures and properties of file contents. It can convert to and from local data element forms including appropriate matching of size, structure, encoding representation (such as locally encrypted data) and data types (e.g., alpha, packed/unpacked numerics, binary, etc.). As such, the layer 6 NVF transformation protocol can be viewed as a component of a network-wide, distributed data dictionary. Another specific layer 6 service module could be a network virtual terminal (NVT) protocol, examples of which are the X.3, X.28, and X.29 recommendations of CCITT, which respectively define terminal characteristics, terminal command language, and PAD (packet assembly/disassembly) procedures. NVT protocols perform the transformations necessary to permit information entry or display between incompatible remote terminals and local, host-resident processes, or between incompatible local terminals and remote processes. Through appropriate mappings, such as between local and generic screen drivers, NVT protocols accommodate the incompatibilities between terminal types.

It should be noted that if communicating processes are of the same nature, or if the information exchange is done according to a universally fixed format, then no transformations may need to take place. When application programs are of a different nature, transformations will always take place. Through the use of services provided by the transformation layer, heterogeneous processes can communicate without undue modifications to the processes or to their existing I/O interface routines.

C.3 LAYER 5 PROTOCOLS

The purpose of the layer 5 protocol in the ISO model is to facilitate simultaneous interactions between processes (or between the layer 6 transformation submodules that support these processes) by establishing, regulating, and terminating concurrent conversational dialogues (or sessions) between these processes. The session may be between a local process and a remote process, or it may be between local processes. As an example of a session, consider a terminal user at one host updating a remote data base. Once the user "logs on" to the data base program, a session between the human and computer processes has been established. The layer 5 protocol then regulates the dialogue flow by ensuring an orderly alteration of update requests and confirmation responses. The session remains in existence until one of the partner processes requests an orderly release. The layer 5 protocol thus links together processes physically resident in different host computers.

AD-A127 171 PENTANET--A REPORT OF THE UNITED STATES AIR FORCE TECHNICAL PANEL FOR A P..(U) MITRE CORP BEDFORD MA R A CREAMER ET AL. MAR 83 MTR-8680 ESD-TR-83-124 2/2

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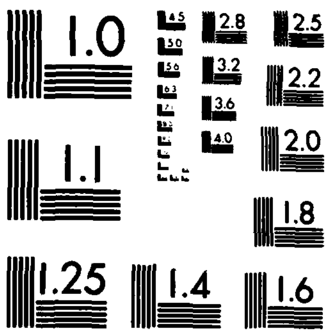
1.0
2.8
2.5
3.2
2.2
3.6
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2.0
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1.25
1.4
1.6

When two processes must exchange information, the initiating process requests establishment of a conversation (session) through its layer 5 protocol. That is, the layer 5 protocol utilizes what, in the X.25 parlance, has been termed "call connect" procedures to establish a virtual circuit or logical connection over which the session will take place. This session establishment procedure may include: (a) setting protocol options to be used during the subsequent conversation, e.g., negotiating the manner by which the communicating processes will alternate their turns to transmit during the conversation, (For example, a terminal operator and a computerized process will more aptly alternate their turns to transmit data rather than exchanging data simultaneously in both directions.), or identifying the higher layer protocol submodules to be utilized during the conversation; (b) mapping the session onto one (or more) particular layer 4 transport path(s); and (c) synchronizing the cooperating source and destination layer 5 protocol layers so that if the end-to-end layer 4 transport mechanism fails, the state of the dialogue exchange will not be lost or, if the session itself fails, session recovery procedures can reset the session to a defined state by resynchronizing and restarting the session from a given checkpoint.

Once a session is established, an unlimited number of variable length information parcels may be exchanged during the dialogue. Furthermore, logically in parallel with this data channel, each session may have a signaling pathway over which short signaling or control messages such as attentions, interrupts or session termination/abort requests may be exchanged.

Upon completion of all data transfers within a session, call disconnect procedures should be evoked for providing an orderly and nondestructive release of the session.

C.4 LAYER 4 PROTOCOL

The purpose of the layer 4 protocol in the ISO model is to relieve the higher layer protocols from any concern with the transportation of information or processing requests between hosts. The layer 4 protocol accomplishes this by enforcing end-to-end network-independent rules, to guarantee the reliable and transparent exchange of entire transactions (not just the packets constituent to a transaction) from host-to-host. The generic layer 4 functions include maintaining error-free, in-sequence, nonduplicate, loss-free transaction

transportation between hosts, multiplexing the session oriented information streams from layer 5 onto the external communication network, and providing host-to-host routing capabilities (e.g., source/destination host addresses) if two or more hosts are permitted to be interfaced to one network node.

A key point is that the layer 4 protocol is network independent. The layer 4 protocol isolates the higher layer protocols from the peculiarities specific to particular external communication networks. The three lowest layers in each host are tailored to interface the host to the specific LAN that may be utilized in a given environment. Networks vary widely as to the types of protocol functions they provide. Intelligent networks, such as X.25, ARPA, AUTODIN, etc., have sophisticated network nodes that guarantee reliable, error-free, in-sequence information transport between network nodes. In a local environment, where such a network node is only a few feet away from the host, there may be no need to replicate the sequencing and error control functions in the host as well as the network node. The layer 4 functions in the host can then be substantially reduced. However, in the event the external network is an unintelligent network, such as several individual point-to-point (host-to-host) links, with unsophisticated network nodes (e.g., modems), a full complement of the layer 4 protocol function must reside in all hosts. Furthermore, in some cases the path between two hosts may involve traversing several networks in series. If any one of the networks is of the unintelligent class, or if any of the intervening network interfaces or gateways are not fully error controlled, the two communicating hosts would again require a full set of layer 4 functions. The positioning of layer 4 functions in each host thus removes the uncertainty of knowing whether or not the type(s) of intervening networks can be configured to guarantee the specified layer 4 host-to-host functions. Thus, host computers can communicate reliably regardless of the characteristics of the connecting network.

C.5 LAYER 3 PROTOCOLS

The purpose of the layer 3 protocol functions in the ISO model is to establish the overall rules governing the operation of the interface between the host and its associated network node, and to support host-to-host connection management activities. There is a unique interface between each specific host and a specific network. Layer 3 functions appropriate to interfacing a host to a particular local area computer network may include: (a) supporting end-to-end connection establishment requests, (b) addressing the outbound transaction to the

proper destination network node, (c) providing transparency to the information in the transaction by encapsulating the transaction with unique transaction start and stop identifiers, (d) routing information to the proper I/O driver when several of a given host's ports interface to the network, (e) servicing the host's I/O driver (e.g., reading and moving information) when inbound information arrives from the network, (f) if need be, segmenting outbound transactions into packets and sequence numbering the constituent packets of each transaction (so that the transaction can be properly reconstructed from its packets once these packets are all received at the destination host), (g) possibly multiplexing the packets of several outbound transactions (or indeed the transactions themselves if they are short enough) onto a single given I/O port, and (h) possibly blocking several small transactions into one packet.

C.6 LAYER 2 PROTOCOLS

The purpose of the ISO layer 2 protocol functions - the so-called data link control functions - is to establish the rules to manage the point-to-point flow of information on each I/O line between a host and its corresponding network node. The layer 2 functions are completely unconcerned with which host process originated (or is to receive) the information being transferred across each I/O line. A great deal of work has been performed by several standards organizations regarding these data link control functions. A coherent set of standard, layer 2 protocol functions have emerged. These functions include the following host-to-network node procedures for each physical link: (a) link set-up and disconnect procedures, (b) packet (or character) data transparency procedures, (c) packet error detection/correction procedures such as parity bits for "single-character" packets, checksum strategies for character-oriented, multicharacter packets, or cyclic redundancy check (CRC) procedures for bit oriented packets, (d) packet flow control procedures along each line, (e) packet (or character) sequence preservation procedures (e.g., packet sequence numbers) along each line, and (f) failure recovery procedures for each line.

Several bit or byte oriented layer 2 protocols have been developed. The bit oriented protocols include vendor specific protocols, such as Digital Equipment Corporation's DDCMP, as well as internationally recognized standard protocols, such as ISO's HDLC (high-level data link control) procedure or subsets thereof; e.g., ADCCP, the U.S. version of HDLC; vendor specific versions of HDLC, such as IBM's SDLC, Burrough's BDLC, Sperry-Univac's UDLC, NCR's NCR-DLC, etc. The byte oriented protocols include: BISYNC, asynchronous teletype, etc.

Unfortunately, vendor implementations of the standard layer 2 protocol functions vary considerably as to the specific functions that are supported. In each instance, any shortcomings of a specific vendor's layer 2 protocol could be compensated for by incorporating appropriate new protocol functions into the vendor package. Alternatively, the end-to-end protocol layers can be designed to recover from any such lower layer shortcomings.

C.7 LAYER 1 PROTOCOL

The purpose of the layer 1 protocol in the ISO model is to identify the mechanical, electrical, functional and procedural details pertinent to the physical link(s) between the host and the network node. The layer 1 protocol details include the type of connectors, the number of pins in each connector, the pin assignment for the connectors, the signaling modes along each line (full-duplex, half-duplex, synchronous, asynchronous, balanced, etc.), and the line speeds. Several standards exist at layer 1. For example; there is EIA's RS232 and RS449, and CCITT's X.21, V.24, and V.35.

C.8 INTRANETWORK PROTOCOLS

The principal resource of a local area network (LAN) is its wide bandwidth communication medium. In order to exploit this resource, achieve communication efficiencies and realize a high degree of connection among the user community, most LAN's have been developed with a multiaccess protocol procedure. These procedures allow the users of the LAN to access the communication facility with maximum operational flexibility and overall communications throughput. The following paragraphs provide a brief survey of multiaccess protocols in the LAN environment. The first paragraph presents a brief discussion of multiaccess protocol attributes after which several different schemes are described. These are followed by a section that addresses the relationship between the intranetwork protocols and the lower layers in the ISO model.

C.8.1 Multiaccess Protocol Attributes

There are several general characteristics of multiaccess protocols which may serve to compare different multiaccess schemes. The purpose of this section is to briefly delineate these as a prelude to the discussion of particular schemes. These characteristics or attributes of multiaccess protocols are:

- Capacity is a measure of the degree to which the multiaccess protocol uses the available bandwidth of the communication medium. It is a direct function of hardware or software procedures required for a general user to gain access to the communication facility.

- Fairness of Access is a measure of the degree to which the multiaccess protocol makes the communication facility available to the user community in accordance with user-dependent demand for service. Methods to achieve fairness range from fixed bandwidth assignment (e.g., fixed dedicated assignment of time slots in TDMA) to demand assignment (i.e., according to real-time assessment of individual user needs) schemes.

- Priority Access is an attribute of multiaccess protocols which describes the means and manner of providing priority (if needed) access to the network. Such mechanisms take a variety of forms ranging from granting multiple time slots in TDMA systems to giving preferred retransmission options in contention-based protocols. This attribute must be carefully considered and trade-offs made, since invariably a priority access mechanism provides service to the high priority user at the expense of low priority users.

- Stability is the attribute of a network which measures its performance under variable load. The performance parameter of interest is transmission delay. As the throughput is increased, in general the delay increases. Under extreme loads the delay may reach a maximum and throughput may decrease and delay may increase on further effort to load the system. This unstable region of operation is to be avoided. The stability attribute is an indication of the extent of the region of stable operation for a given multiaccess protocol scheme.

These attributes may be used by the system designer as guidelines in selecting schemes for a particular application.

C.8.2 Random Access Methods

An important class of multiaccess protocols come under the heading of Random Access Schemes. In this scheme each user contends with the rest of the user population for access to the entire communication facility. The method was designed with the intent of serving those situations in which there is a large number of users each transmitting bursty traffic, i.e., traffic with a high peak-to-average ratio. In such an environment these schemes can efficiently utilize the communication medium and effectively interconnect the entire user population. Characteristic of this access method is the occurrence of collisions, i.e., simultaneous or overlapping access attempts, which must be resolved by some mechanism. This collision control mechanism generally becomes the identifying name of the several types of schemes which fall under this category.

C.8.2.1 Polling. The polling scheme for providing multiple access to a network resource (Host Computer) was commonly used in time sharing systems and simple network configurations employing multidrop lines. In this scheme, control of the communication facilities is retained by a central processor (e.g., the host processor) which interrogates terminals attached to the network by means of address-specific polling messages. If a polled terminal is ready to send a message, it does so; otherwise it sends a negative reply (or NAK). From the standpoint of the central processor this scheme allows a controlled means of mixing communication requests for resources with other processing demands. However, for communications within a LAN this scheme may require a control node thus creating a possible single point of failure. Polling techniques in a LAN generally are inflexible and highly inefficient in use of bandwidth.

C.8.2.2 Reservation TDMA. Reservation Time Division Multiple Access (TDMA) is a multiple access scheme in which users are allocated access to the LAN communication medium in terms of a number of time slots. A central facility of the LAN controls the allocation process and reserves slots for a particular user after he requests access through an internal protocol. The internal protocol may be quite complex and can increase cost and complexity of the hardware necessary for time slot synchronization. The scheme works well when the user population transmits relatively long duration messages as opposed to bursty transmissions.

C.8.2.3 CSMA and CSMA/CD. Carrier Sense Multiple Access (CSMA) and CSMA with collision detection (CSMA/CD) are random multiple access protocols which require that the user communication interface device "listens" to the medium to detect when the communication facility is free before making an attempt to transmit. If another user is transmitting, the listening user delays his attempt to transmit after

a specified or random time interval. CSMA/CD attempts to further increase system efficiency by including a collision detection mechanism which allows two colliding parties to monitor the collision and subsequently reschedule their transmission attempts at disjoint random further times. This scheme has received much attention both theoretically and from a practical standpoint. CSMA/CD schemes can exhibit very good capacity (98 percent) and high stability under overload conditions. This scheme is attractive because of its simplicity.

C.8.3 Intranetwork Protocols/ISO Hierarchy

Although activity in the LAN intranetwork communication protocol arena has been underway for several years, the work done by LAN system designers and equipment vendors has been performed independently without consideration of standardization. Thus, even though the resultant intranetwork protocols, in principal, often performed similar functions as those performed by the lower layers in the ISO model, their implementations not only were substantially different from the ISO concepts but also were substantially different between vendors. Hence, a one-to-one relationship between "layers" of LAN intranetwork protocol and the lower layers of the ISO model generally are difficult to define.

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